Dalton (J. S.)

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THE BOOK OF

PHILOSOPHICAL EXPERIMENTS.

ILLUSTRATING

THE PRINCIPAL FACTS AND CURIOUS PHENOMENA OF

ELECTRICITY, GALVANISM, MAGNETISM, OPTICS, CHEMISTRY, HEAT, ETC.

WITH INTRODUCTORY OBSERVATIONS ON EACH SCIENCE, AND UPWARDS OF 300 EXPERIMENTS.

BY J. S. DALTON.

TO MY KIND FRIEND, JOHN ALLISTON, ESQ.,
One of the Directors of the Provincial Bank of Ireland, a Governor of Christ's Hospital, &c, &c.
I MOST RESPECTFULLY DEDICATE THIS LITTLE VOLUME, AS A MARK OF MY HIGH RESPECT AND ESTEEM FOR HIS CHARACTER, AND AS A SLIGHT REMEMBRANCE OF HIS KINDNESS TO

THE AUTHOR.

☞ THIS work has two objects in view. First, to provide young persons with the means of obtaining a knowledge of some of the most important phenomena of nature, and the applications of science to purposes of utility; and secondly, to furnish them with an almost inexhaustible fund of amusement for winter evenings, and other occasions, when exercises in the open air are obliged to make way for in-door recreations.

There is no person, however illiterate, but experiences some degree of pleasure on witnessing the performance of scientific experiments; and young persons are more particularly delighted with them. It is hoped, therefore, that the volume now offered to their notice will be accepted with pleasure, as it will enable them, not only to understand many curious facts in nature, but will instruct them also how to perform a great variety of beautiful experiments themselves, without risk or danger.

For conveying instruction in the sciences, experiment is superior to every other method. A person who performs an experiment, and thoroughly understands the nature of it, will hardly ever forget the principle it illustrates; because the fact will be impressed upon the memory in the strongest manner. Young persons may learn, by experiment, what cannot be taught them by mere description; and the natural curiosity of youth leads them to desire earnestly to become acquainted with the principal laws of nature. No amusement is more gratifying to them than to be engaged in this way; and hence the pleasure with which they peruse such works as the "Endless Amusements," and others of a similar description.

These works, however, have been generally deficient in an important particular: they do not explain the *causes* of the effects they describe, and they are, consequently, much less interesting and instructive than they might be made. This fault has been remedied in the present work; and such directions are given, that no possible danger can be incurred in performing the experiments. Some elementary books on science contain a number of scientific illustrations, that cannot be performed without considerable risk, even by persons who are familiar with the subject: what must be the danger, then, when ignorant persons attempt to perform them, without having received the least caution? Serious accidents are frequently the result. In this work, experiments that cannot be performed without danger are omitted, and cautionary remarks are given whenever necessary, in order to prevent the possibility of accident.

As the "Book of Experiments" is intended chiefly for the amusement and instruction of young persons, it will not be expected to contain any elaborate views of science. It has been the endeavor of the Editor to collect and arrange only such experiments as might easily be understood, and such as explain, in a pleasing manner, the principles of many of the phenomena of daily life. Some of the illustrations are derived from sources not easily accessible; others are those which the most eminent scientific lecturers of the present day are in the habit of employing; and the remainder, it is believed, have never before been published. The whole are simple and striking, and will, it is hoped, have the effect of stimulating the minds of those who practice them to become still better acquainted with "divine philosophy;" and, by observing the beautiful harmony that pervades the whole material universe, "Look through nature up to Nature's God."

ELECTRICITY.

Introduction to the science—Theories of electricity—Conductors and non-conductors—Rapid transmission of electricity—Galvanism—Magnetism—Description of an electrical machine—a Leyden jar—How to make cheap electrical machines of paper—Ditto of glass—How an electrical machine acts.

1. THE word electricity is used to express the cause of a great variety of phenomena, which take place when certain substances are rubbed against each other; and it is found, by experiment, to be identical with lightning. It is supposed to be an extremely subtle fluid, which nearly all bodies are capable of producing under certain circumstances. It is commonly obtained for the purpose of experiment, by the friction occasioned by rubbing glass with silk. An arrangement of these substances, in a peculiar manner, constitutes an electrical machine, by which large

quantities of the electric fluid may be obtained. When thus accumulated, it is found to possess the power of passing through some substances with extreme facility, which are, therefore, termed good conductors; while other bodies retain it entirely, or very much impede its progress; such substances are termed non-conductors, and are usually employed for the purpose of obtaining electricity by friction, as before mentioned. The electric fluid obtained by the electrical machine, and that obtained from the clouds, which is lightning, are identical in their properties; and the electricity procured by either method is found to cause attraction and repulsion between bodies; to be capable of decomposing water and other chemical compounds, into their elements; and when passed through living bodies, in considerable quantities, of destroying life. It travels with an inconceivable velocity, like light, through good conductors, passing only along their surfaces; and it is, undoubtedly, the cause of many vital and chemical phenomena, as well as being closely identified with galvanism and magnetism.

It is wonderful to think that "the forked lightning," which, at all times, presents an appearance that cannot be contemplated without some degree of awe, and which, occasionally, is terrific, is identical in all respects, except that it is more powerful, with the electric spark that may be obtained from a common sheet of paper, as described hereafter. Yet such is undoubtedly the case; for Franklin, and other philosophers since his time, have drawn lightning from the clouds by means of silk kites, and found it resemble, in every respect, that which they obtained from an electrical machine.

Some philosophers have supposed that there are two kinds of electricity, which they have termed *resinous*, because it is produced abundantly from resinous substances, and *vitreous*, because procured from glass. Dr. Franklin supposed that there were not two kinds of electricity, but that it existed in two different conditions, which he termed *positive* and *negative*. These distinctions will be best explained by the experiments: it is only necessary now to mention that, whichever theory of electricity is preferred, the same facts are explicable by both of them, since substances, in a *similarly* electrical condition, always *repel* each other, and when in *opposite* states, they *attract* each other. This is illustrated by experiment 18.

3. Electricity is not produced by the friction of two portions of one substance, but when different substances are rubbed together, the electric fluid is obtained; and, if the bodies employed are bad conductors, it accumulates, according to the time the friction is continued; while, if the substances are good conductors, it passes away as quickly as it is obtained, and the usual phenomena does not take place.

The worst conductors are, therefore, the best substances from which electricity can be produced; amber, wax, glass, silk, hair, and dried wood, are a few of these. Steam and vapor, smoke, living animals, vegetables, water, and the different metals, are good conductors; and little or no electricity can therefore be procured from them, since they conduct it away as quickly as it is obtained. Bodies having points on their surface readily give off, as well as receive, electricity; and are, therefore, unfit to be used for the purpose of retaining it.

Lightning conductors—the long, pointed rods of iron that are placed against high chimneys and buildings, in order to prevent their being struck by the electric fluid—are examples of the manner in which a knowledge of the facts just related may be applied to useful purposes. Iron, being one of the metals, is a good conductor; and when, therefore, a cloud, charged with electricity, passes near it, it establishes a communication between the earth and the cloud, and thus prevents the serious consequences which ensue when the electric fluid endeavors to find a passage through a bad conductor. As just mentioned, living vegetables are good conductors; and it therefore frequently happens that a cloud discharges itself by means of a tree; but in passing through it, the vitality of the tree is destroyed, in the same way that animals may be killed by having a powerful shock passed through them. It is extremely dangerous for persons to take shelter under a tree during a thunder storm; because, if the tree be struck by lightning, it may probably pass through their bodies in descending to the earth, as they are as good conductors as the tree.

4. The rapidity with which lightning travels is inconceivable; and it is the same with the electric fluid procured artificially. A wire has been attached to a portion of an electrical battery, and after being extended for two or three miles, in folds, the other end has been made to communicate with an explosive compound, in order to ascertain how much time would expire between the discharge from the conductor and the explosion. In every case they appeared to take place *at the same moment;* and all other experiments that have been performed for a similar purpose, have tended to prove that the passage of the electric fluid is instantaneous.

The principal phenomena of electricity will be found described and illustrated in the following experiments; among them, also, are a few in galvanism and magnetism, which must, therefore, be briefly alluded to.

5. Galvanism is so termed from the nature of the person who first noticed some of the remarkable effects it is capable of producing. Galvani found, that when he brought the point of a knife in contact with the nerve of a frog, a portion of whose body was in contact with the prime conductor of an electrical machine, that the animal was violently convulsed; and following up these experiments, by the assistance of a friend, he constructed what is termed the galvanic battery. This consists of a number of plates of zinc and copper, placed side by side, and immersed in a dilute acid, which, acting on the surface of the metals, produce a current of galvanism, that, passing off at each end by means of two wires, may be made to form a circuit through any substance. All the metals, when exposed to galvanic influence in this way, become liquid, and compound bodies are decomposed; the elements in a positive state of electricity passing off to one pole, and those in a negative state to the other. Illustrations of these facts will be found in the ensuing pages, where a description is likewise given of the best means of constructing a

galvanic battery, and a voltaic pile, and how to illustrate their effects.

6. Magnetism is the term used to express the property of the loadstone, with which most persons are familiar. It is well known that the loadstone will attract iron and steel, and that the latter, by being rubbed on the loadstone, becomes a magnet; one end of which will always point to the north pole, and the other to the south. The advantages that man has derived from this circumstance in being able, at all times, to determine with exactness his situation at sea, when surrounded on all sides with an apparently boundless ocean, are too well known to require comment.

It has only quite lately, however, been determined that the direction of the magnet is occasioned by currents of electricity, which are constantly passing across the earth from west to east, and that the magnet is, therefore, always at right angles to this current. That this is the case, however, is clearly proved by experiment 79. It is also capable of proof that magnetism is a modification of electricity. By experiment 77, it will be seen that, by passing a current of electricity round a steel bar, it becomes a magnet, possessing all the properties of one formed by friction on a loadstone; and electro-magnetic machines may now be seen in the opticians' shops, by which the electric spark can be procured from magnets themselves.

SIMPLE ELECTRICAL MACHINES.

7. A few of the more important effects of electricity can be exhibited without the assistance of an electrical machine; yet it is so very expensive a piece of apparatus, and so liable to accident, that few of our readers will probably be induced to purchase one from a mathematical instrument maker. They may occasionally be met with cheap, second-hand; but as few persons have the opportunity of procuring them in this way, we have described, in the following pages, several methods by which, with a little ingenuity, and at a trifling expense, any one may make a good electrical machine for himself.

The principal parts of a good machine are, *a cylinder*, or a plate of glass, from which electricity is to be obtained by causing it to rub against *a piece of silk*, covered with *an amalgam;* the method of preparing which will be described hereafter.

As the electricity accumulates, it is passed to a hollow cylinder of metal, supported on a glass leg, so that the electricity cannot escape from it, which is called *the prime conductor;* and from this reservoir, such quantities of the electric fluid as may be required, can be obtained. It is necessary that the rubbing surfaces should be connected, by a *chain*, with the ground, or otherwise: in a short time, the silk is incapable of giving off any more electricity, being, in fact, insulated by the dry wood of the table on which it may be standing, just as the prime conductor is by its glass supporter.

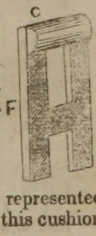
8. A Leyden jar is used to contain electricity, so that when many of them, of large size, are attached together, a great quantity of the fluid may be accumulated, and then the most powerful effects can be produced. The jar is formed of glass, and is coated, inside and out, with tin foil, by which the electricity is diffused over both surfaces. A description of the best method of making one cheaply will be found in a subsequent page.

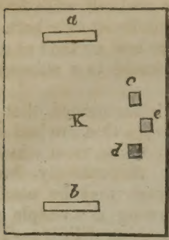
9. It has been previously mentioned, that not only glass, but all substances that are bad conductors of electricity, are the best from which to obtain the electric fluid. Accordingly, brown paper, being a non-conductor, may be used for the purpose; and the following is a simple plan for making an electric machine with it:—Take a circular piece of wood, about one inch thick, and of convenient diameter, and paste over it a sheet of brown paper, cutting the edges even; then paste a strip all round the edge of the circle, and when quite dry, paste on another coating of the brown paper in the same manner; then cut a square hole in the centre, and pass through it the axle, which mount on two pieces of wood as pillars. A piece of wood, staple-shaped, and covered with silk, or woolen cloth, will do for the rubber; and a cylindrical piece of wood, like a rolling-pin, with rounded ends, covered with tin foil, and mounted on a wine bottle, serves for the prime conductor; three or four wires or needles, being inserted in the wood, to collect the electricity from the two sides and edges of the wheel.

10. A glass electrical machine, of the cylindrical form, may be made at a very trifling expense. The following is an extremely ingenious method of constructing one from the most simple materials:—

First, drill a sufficient hole through the bottom of a common wine bottle, opposite the mouth; or take off the bottom, by igniting a piece of worsted tied round it dipped in turpentine, which will do this. Through this hole and the mouth, pass a spindle, as represented in the engraving (B, C,)

The end of B should be squared, to fix a handle on, and the spindle should be fixed firmly in the bottle. The bottle is then to be fixed in a frame (as represented at page 42,) in the following manner:—the end of the spindle C passes through a hole, the diameter of which is the same as that of the spindle in the upright D, and the end B slides down the grove in the other upright, F, the bottom of which is the same hight as the hole in the upright C, so as to keep the bottle in a horizontal position; the spindle is kept from starting up by passing a pin through the upright, in the direction of the line *a*. Next, make a cushion of wash leather, stuffed with wool, and fasten it with glue on the top of a frame, F, as represented in the annexed cut. This frame is to be of such a hight, that the cushion shall press against the side of the bottle; and a piece of black silk (which, for the sake of clearness is omitted in this engraving, but is marked A, in the one at page 42,) is to be sewn on the top of the cushion, and hang over the bottle, as represented in page 42. The method of keeping this cushion

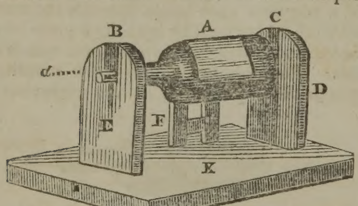




pressing against the bottle will be better understood by reference to the following figure, which is a plan of the board, K, in which the uprights are fixed; *a* and *b* are the places for the uprights; *c* and *d* are the holes in which the ends of the cushion frame are put. A long wedge (see cut on the right) is put

in the hole *e*, and another wedge is then put between the cushion frame and the upright wedge. This is better explained by the following engraving, where F, is a side view of the cushion from L, the upright wedge, and M, the wedge which is put between the cushion frame and the upright wedge.

The cushion should be smeared with an amalgam, formed by melting together, in the bowl of a tobacco-pipe, or in a crucible, one part of tin, with two of zinc; to which, while fluid, six parts of mercury should be added, and stirred about till cold, when it is to be reduced to fine powder in a mortar, and mixed with a sufficient quantity of lard to form a paste. If this cannot, however, be easily obtained, a little quicksilver, scraped from the back of a broken piece of looking-glass, and mixed with tallow, may be used instead. When this is done, the machine will be complete, and its appearance is represented in the annexed engraving. The letters refer to the part before described. If the cushion be pressed

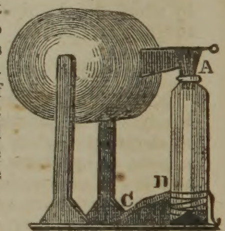


against the bottle with the hand, it will cause the machine to work better; and before it is used, it should be held before the fire for a minute or two, in order that the bottle may be perfectly dry, as moisture conducts the electricity away. This is the reason why many experiments, which succeed on a clear, dry day, fail when the atmosphere is filled with moisture.

A prime conductor for the above machine may be made thus :—at right angles to one end of a cylinder of wood, about two inches and a half in diameter, and six inches long, fix a small wooden cylinder, about three quarters of an inch in diameter, and three inches long, rounded at both ends; the other end of the larger cylinder is also to be rounded. Cover the whole with tin foil, and mount it on a stand on a glass rod. When used, it is to be placed with the cross-piece in a line even with, and about half an inch from the bottle; and it should be of such a hight as just to come below the silk apron. When it is wished to charge a Leyden jar, it is to be placed at the round end of the conductor.

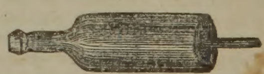
11. The mode in which the electrical machine just described, and others, act, will be easily understood from the following description :—The friction of the cushion against the glass cylinder (bottle,) produces a transfer of the electric fluid from the cushion to the bottle; that is, the cushion becomes negatively, and the glass positively electrified. The fluid which thus adheres to the glass, is carried round by the revolution of the cylinder, and its escape is at first prevented by the silk flap which covers the cylinder, until it comes to the immediate vicinity of the part that projects from the prime conductor; and which, being placed at a small distance from the cylinder, absorbs nearly all the electricity as it passes near it, and transfers it to the prime conductor. Positive electricity is thus accumulated in the prime conductor, while the cushion, being deprived of its electricity, is negatively electified.

12. An electrical machine may be made, without the trouble of forming a hole through the bottom of a bottle, by attending to the following directions :—The rubber is to be glued to a piece of wood, which is then to be inserted into the neck of a small bottle, as shown by A in the engraving annexed, and secured by sealing-wax. A piece of leather should then be tied tightly near the bottom of the bottle, at back, as at B, the end of which is to be nailed to the stand to secure it, as a hinge. In front of the bottle is then to be tied a piece of Indian rubber, the end of which is also to be made fast to the stand, as at C, so that when the rubber is pressing against the cylinder, the elasticity of the Indian rubber permits the cushion to yield to the inequalities of the cylinder, and the pressure is always nearly equal. D, represents the cylinder; and above A, is a



knob (a piece of bent wire may be used instead,) to receive the spark from. If the cylinder is made of a green glass bottle, the positive spark will be given out by the rubber, and the negative by the conductor; but if of white glass, the contrary will take place.

13. One of the greatest difficulties in constructing the machine first described, is making a hole in the bottom of the bottle, which is to serve as a cylinder. This difficulty may be avoided by fixing a piece of wood in the centre of the concavity at the bottom of the bottle, while melted sealing-wax is dropped in until the stick is well surrounded, as in the accompanying figure. On the wax, cooling, the stick will remain quite firm.



Care should be taken to fix it exactly opposite the spindle that is to be fixed in the neck of the bottle.

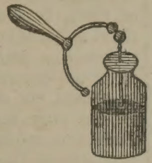
Thus, with a little ingenuity, any one who wishes to study the science of electricity may easily make himself a cheap machine for the purpose; and by doing so, he will have the additional advantage of perfectly understanding the different parts of which it is formed.

EXPERIMENTS.

Electrical attraction–Repulsion–Electrified ribbons–De Luc's column—Identity of the electric fluid—Positive and negative electricity—The discharging rod—Working power of electricity—Electricity from a cat's back—Electrometers—To draw sparks of fire from the body—To ignite ether by the touch—Electrified head of hair—An electrified kiss—The ringing bells—The jumping balls—The The sportsman—Luminous figures by electricity—To imitate the sound of thunder—Imitation thunder clouds—The cause of thunder—Place of safety in a thunder storm—Electrified sheet of paper—The electrophorus—To charge the electrophorus—Description of the electric spark.

THE LEYDEN JAR.

14. This is one of the most useful pieces of electrical apparatus. It is employed for the purpose of containing a quantity of electricity, which may thus be applied to any substance. It consists of a glass jar, coated, both inside and out, nearly to the top, with tin foil, by which the electricity is equally distributed. A knob rises through a wooden top, communicating with the inside of a jar. When it is wished to change it, this knob is applied to the prime conductor of an electrical machine in action, and the jar will remain charged till a connection is made, by some good conductor, between the knob and the outside tin foil.



15. A Leyden jar may be made out of a common wine bottle, with about three inches of iron filings in it, and filled to the shoulder with water. Coat it on the outside with tin foil, and pass a wire through the cork, one end reaching the iron filings, and the other terminating in a brass knob. By this means, the necessity of coating the inside of the jar with tin foil, a work of much difficulty, may be avoided.

ELECTRICAL ATTRACTION.

16. If a piece of amber be rubbed on a coat-sleeve for a short time, or on a piece of silk, which is preferable, it becomes electrified, and will attract light substances, &c. It was the discovery of this peculiar property of amber that first directed the attention of philosophers to electrical phenomena.

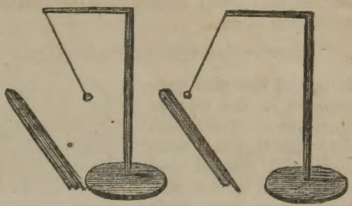
17. If a piece of sealing-wax be rubbed in a similar manner to amber, it will exhibit the same properties.

ELECTRICAL REPULSION.

18. Electrify a smooth glass tube with a silk rubber, and hold a small feather at a short distance from it; the feather will immediately fly to the tube, and adhere to it for a short time, and then fly off; and the tube can never be brought close to the feather till it has touched the side of the room, or some other body that communicates with the ground. If, therefore, the operator take care to keep the tube constantly between the feather and the side of the room, he may drive it round to all parts, without touching it; and the same side of the feather will be constantly opposed to the tube.

19. If, while the feather is flying before the smooth tube, an excited rough tube, or a stick of sealing wax, be presented to it, it will fly continually from the wax, or from one tube to the other, till the electricity of both is discharged. This was one of the first, and is one of the most common experiments in electricity: it is, however, very entertaining, and well exemplifies electrical attraction and repulsion.

20. If the feathers be attached by threads of silk, the experiments may be performed as represented below, where the left-hand figure represents the pith ball attracted by the glass tube, and the right-hand figure the same ball, when charged with electricity, and repelled by the tube.

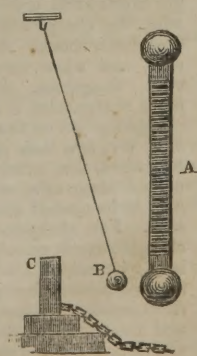


ELECTRIFIED RIBBONS.

21. If a white and a black ribbon, about two or three feet long, and perfectly dry, be applied to each other by their smooth surfaces, and then drawn frequently between the finger and thumb, so as to rub against each other, they will be found to adhere together; and if pulled asunder at one end, will rush together with great quickness. While united, they exhibit no sign of electricity, because the operation of the one is just the reverse of that of the other, and their power is neutralized. If completely separated, however, each will manifest a strong electrical power; the one attracting those bodies which the other repels. One is positively electrified, the other negatively.

DE LUC'S COLUMN.

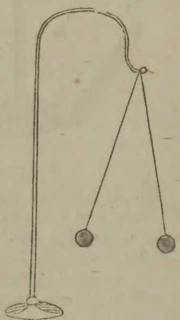
22. The nearest approach to a perpetual motion, by means of apparatus, is represented in the following figure, known as De Luc's column. It consists of a glass tube, closed at each end by a brass knob, and containing a number of pieces of Dutch leaf, with paper placed between them. By this means electricity is produced, and may be made to attract the pith ball, B, which is suspended by a silk thread between the column and C, a piece of wood, covered with tin foil, communicating by a chain with the ground. After the ball has become charged by contact with the column, it is repelled, and then flies to the tin-foil conductor, where it parts with its excess of electricity, and becomes negative, returning to its perpendicular position, to be again attracted and repelled, as before. By this means the ball will continue in action as long as any electricity is generated, and this may continue for years.



BODIES SIMILARLY ELECTRIFIED REPEL EACH OTHER.

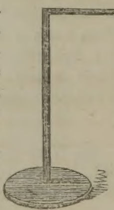
23. If two pith balls be suspended by pieces of silk thread, and electrified, by being touched with excited sealing-wax, or the flannel with which it has been rubbed, the balls will then fly apart from each other; but if one of them be touched with the wax and the other with the flannel, they will then mutually attract each other, and adhere together. This experiment illustrates, exceedingly well, one of the principal laws of electricity mentioned in the Introduction; namely, that bodies similarly electrified *repel* each other, but that when dissimilarly electrified, they *attract* each other.

IDENTITY OF THE ELECTRIC FLUID.



If one of the pith balls mentioned in the last experiment be electrified with sealing-wax that has been rubbed with flannel, and the other ball by silk rubbed with glass, these balls will repel each other (as seen in the figure) which proves that the electricity of the silk is the same as that of the sealing-wax; both substances being non-conductors, and, consequently, electrics.

TO SHOW POSITIVE AND NEGATIVE ELECTRICITY.



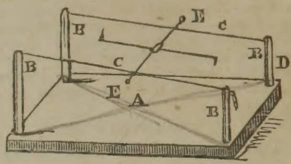
25. To show what Franklin termed "positive and negative electricity," and Dufay, "resinous and vitreous electricity, and that the one is produced from a conductor, and the other from a non-conductor, let one of two balls be electrified by sealing-wax, and the other by glass; they will then mutually *attract* each other, showing that they are oppositely electrified.

THE DISCHARGING ROD.

26. When a Leyden jar is charged with electricity, the inside and the outside are in different states. An equilibrium may be restored, by applying the thumb to the outside, and the fore-finger to the knob communicating with the inside, when the charge will pass through the body, and occasion a shock. As this is sometimes unpleasant, and when very powerful, even dangerous, the annexed piece of apparatus is used to discharge the jar. A, is a glass handle; C C, two balls placed upon two wires, D D, which should be upon a hinge at B, so that they may be be opened wide, if necessary. For cheapness, the discharger may be merely a piece of bent wire, with a handle of dry wood, which is a non-conductor, like glass. When a jar is to be discharged, place one knob on the *outside* of it, and the other on the knob at the top. Be sure and touch the *outside* first; for if the knob on the jar is touched first, a severe shock will sometimes be given to the experimenter.

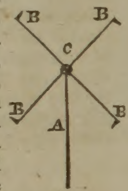
WORKING POWER OF ELECTRICITY.

27. Electricity may be made to give motion to bodies in the following way:—A, is a wooden board, into which are fixed four glass pillars, B B B B; the two which stand opposite D, are to be shorter than those placed at the back of the board; from the top of these stretch fine wires,



C C; at D have a chain attached to your conductor; place on the wire a wheel made of four pieces of wire,, two to be bent round at the ends; fix them in pieces of wood, F; the other two to terminate in a point, and to be fixed in the piece of wood the contrary way to the others; the points to be bent, the one up and the other down, as seen in the engraving. The electricity passes from the prime conductor up the chain at D, over the chains B, up the wire C, on to the wheel, and off at the points, which causes it to turn round, and wind itself up the inclined plane. Electricity flies off very quickly from points; indeed, a candle may sometimes be blown out from a sharp point on the prime conductor, when charged.

28. A rotary motion may be obtained by the instrument represented in the annexed cut. A, is a wire, to be placed on the conductor of an electrical machine; and the four wires, B B B B, are to be fixed on the top, and bent so as to turn freely on their axis at C. When the machine is put in action, the electricity flies off from the points, and by the re-action of the air, the wires are forced quickly round.



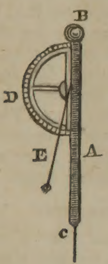
ELECTRICITY FROM A CAT'S BACK.

29. Hair, as previously mentioned, is a non-conductor, and, therefore, may be employed to obtain electricity from. Some amusing experiments may be performed with a living cat, by making the hair on her back act as a portion of an electrical machine. Make friends with Pussey—if a black one, so much the better—and warm her back well by the fire; put her on your lap, and place your left hand round her throat, so that your thumb and finger may nearly meet at her shoulders. Then pass your right hand up her back, and a slight electrical shock will be felt.—If the experiment is performed in the dark, the electric spark will be distinctly visible. The *rationale* of the experiment is, that the hand, acting as the rubber of an electrical machine, in passing along the cat's back, gives out a portion of the electric fluid, which the left hand, performing the part of a prime conductor, carries off; and when the right hand approaches the left again, the electricity flies from one to the other, and restores the equilibrium, at the same moment giving out the spark, and thus causing the shock.

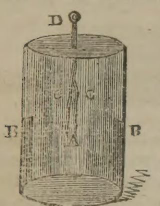
ELECTROMETERS.

30. An electrometer is an instrument used for the purpose of detecting the presence of electricity in any substance. The woodcut represents a common glass bottle, which will form a cheap piece of apparatus; on each side of it is placed a small piece of gold leaf. In the centre *a*, are two pieces of gold leaf, suspended by a piece of wire passing through the cork. By means of this instrument, very slight portions of electtricity may be discovered; for immediately the knob which rises through the cork comes in contact with a body containing electricity, the centre leaves fly apart.

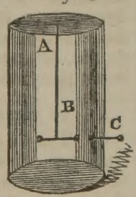
31. The most common form of electrometer is one usually fitted to the prime conductor of a machine, and represented in the following engraving. A, is a piece of wood, terminating in the knob B, in order to prevent the electric fluid passing away, which it would do were the top pointed. C is a wire, by which the instrument is fixed in the conductor; D is a piece of ivory, divided into regular portions; and E is a piece of wood, terminating in a pith ball. According to the power of the electtricity, so will the ball rise; and as the piece of ivory is graduated, this may be easily ascertained.



32. The form in which the electrometer first described is sold by opticians, is represented by the subjoined cut. It is called Bennett's electrometer. A, is a glass jar; B, the sides, coated part of the way up with gold leaf, or tin foil; C C, two pieces of gold leaf, a ttached to the ball D, to which the body containing electricity is to be applied.



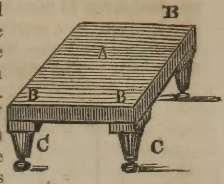
33. One of a simple kind, that may be more easily made than those previously mentioned, is constructed on Coulomb's principle. A, is a glass jar; B, a silk thread, supporting a piece of wood, having a fine ball of pith at each end; C is a wire, passing through one side side of the jar. When an electrified body is brought into contact with the knob on the end of this wire, the pith balls will be attracted or repelled, according to the state of electricity they are in.



TO DRAW SPARKS OF FIRE FROM THE BODY.

34. If a person is insulated (that is, placed upon some non-conducting body,) and then made to receive a quantity of electricity, on presenting any conductor to him, a portion will pass off, giving out the usual electric spark.

35. The best means of insulating a person is, to place him on an electrical stool, taking care that his clothes do not touch any of the furniture of the room, or it will convey the electricity back to the earth as fast as it is obtained by the machine. The stool is to be made as represented in the cut. A, is a piece of deal board, at the four corners of which are to be glued four pieces of the same kind of wood, very dry (B B.) These are to rest on the legs, made of the necks of wine bottles (C C,) or other pieces of glass, which, being non-conductors, will not allow any electritricity to pass down to the earth; and thus, a person standing on this stool is completely insulated.



Let a person stand on this stool, and with one hand take hold of the conductor of an electrical machine while in action. Sparks may now, by presenting the knuckle, be drawn from any part of his body as easily as from the conductor itself.

TO IGNITE ETHER BY MERELY TOUCHING IT.

36. While a person is on the stool, charged with electricity, let some one approach him with a warm spoon, containing a few drops of ether. If he now brings the knuckle of his hand not connected with the conductor within a short distance of the spoon, a brilliant spark will be given off, and ignite the ether.

THE ELECTRIFIED HEAD OF HAIR.

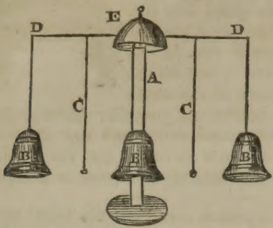
37. While a person is on the electrical stool, if he is charged with much electricity, "each individual and particular hair will stand on end." The electrical head is an amusing toy to illustrate the same fact. Get a wooden head (the more frightful the better,) and fix some long hair on it, then place a strong wire in the neck to support it by, and fix it in the conductor of an electrical machine. When the machine is put in action, the hair will rise up, and make the figure present a frightful appearance.

THE ELECTRICAL KISS.

38. An amusing experiment may be performed with the electrical stool. Let any lady challenge a gentleman, not acquainted with the experiment, that he will not be able to kiss her, although she may offer no opposition. If he accept the challenge, let her stand upon the stool, and with one hand take hold of a chain in connection with the prime conductor of an electrical machine. If it is then put in operation, and the gentleman approaches the lady, directly he attempts to kiss her, a spark will fly in his face, which will almost certainly startle him, and prevent him effecting his object. The clothes of the parties must not come in contact, or the spark will not be given off.

THE RINGING BELLS.

39. A small peal of bells may be made to ring by electricity, in the following way:—A is a glass pillar, fixed in a stand of wood, from the top of which proceed the wires D D, terminating in brass bells. The electrical apparatus is then at-



tached to the ball (E), and little metal tongues are to be hung between the bells by silk, as at C C. The middle bell is to have a hole at the top, for the glass pillar to pass through. When the machine is charged, a very pretty effect will be produced. The electricity passes down the wires D D to the bells, which are then positively electrified, and attract the clappers, C C, that are negatively, in consequence of being insulated by the silk strings, which are non-conductors. The bells, therefore, attract the clappers, just as the pith balls were in a former experiment, until they are charged, when they strike against the centre bell to discharge themselves; and thus continue flying between the bells until all the electricity is taken from the side bells. The bottom of the pillar should be coated with tin foil, from the bell downward.

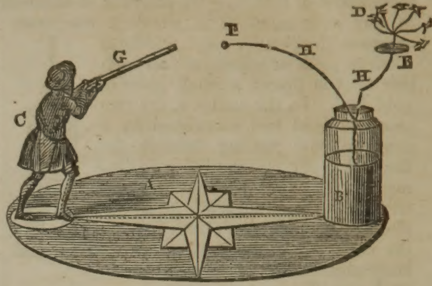
JUMPING BALLS.

40. Get two pieces of wood, and coat them with tin foil, or two pieces of metal plate; attach one of them to the prime conductor by a chain, and let it hang about two or three inches from a table. Then place some pith balls upon the bottom piece of wood (B), and bring it under the other (A). Immediately this is done, and the upper piece is charged with electricity, the pith balls will begin to jump from one to the other with great rapidity. The cause of this is, that the upper piece of

wood being charged with positive electricity, attracts the balls till they become positive also, when they are repelled; but parting with their electricity, are again attracted, and so they keep flying from one to the other, until an equilibrium is restored. Some paper figures may be made to dance on the bottom plate, instead of the pith balls, if it is wished.

THE SPORTSMAN.

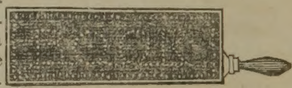
41. The piece of apparatus that is called by this name is capable of affording much amusement. A is a stand of wood; B is a common leyden jar, out of which proceed the wires H H, one terminating in the ball F, the other in the ball D, to which are attached a number of pith birds by silk strings; E is a shelf for the birds to rest on; C, a sportsman; G, his gun. To put the apparatus in action, charge the leyden jar with electricity, by affixing a chain to the bottom part of it, and connecting it with an electrical machine, or



by applying it to a prime conductor, when the birds will fly off from the knob to which they are fixed, in consequence of being repelled. If the sportsman and gun be then turned, so that the end of his gun shall touch the knob F, an electric spark will pass from one end to the other, a report will be heard, and the birds will fall down as if shot, in consequence of the electricity having been taken from the leyden jar. There should be a communication between the sportsman and the jar, formed of tin foil, or some metal, as shown by the dotted line on the stand.

LUMINOUS FIGURES BY ELECTRICITY.

42. While the electric fluid passes along a conductor, without interruption, it is not perceived; but whenever the connection is broken, a spark is produced. If, therefore, a figure be formed on glass with tin foil, as represented in the wood cut, by separating it at regular intervals, a chain of fire will be exhibited when the instrument is connected with an electrical machine.



If the tin foil is separated, so that the vacant spaces form the letters of a name, or any particular figure, it will increase the interest of the appearance. It is merely necessary to hold the instrument to the prime conductor of a machine, and the electricity will follow the windings of the tin foil, till it reaches the other end. The experiment should be made in the dark.

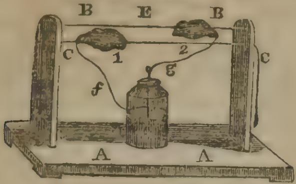
TO IMITATE THE SOUND OF THUNDER.

43. Take a piece of sheet iron, about three feet long, and one foot wide, and holding it downward at one corner, move the hand gently, so as to shake it in the direction of its length. By this means, a great variety of sounds will be produced, varying from the deep growl of distant thunder to those loud and explosive bursts which rattle, in quick succession, from clouds immediately above our heads. The same effect may be produced by sheets of tin plate, but, on account of their small size, the sound is shorter and more acute.

TO MAKE IMITATION THUNDER CLOUDS.

44. The annexed wood cut will afford a clear idea of the manner in which thunder is supposed to be produced. A A is a wooden stand on which are erected two uprights, B B; C C are two small

pulleys, over which a silken cord (D) can pass easily; E is another silken line, stretched across



from one upright to the other; on these silken cords, two pieces of thin card-board, covered with tin foil, and so cut out as to represent clouds, are to be fixed horizontally, and made to communicate by means of the thin wires, *f* and *g*, one with the *inside*, and the other with the *outside*, of a charged jar (I). Now by pulling the loop of the silk line D, the cloud 1 will be brought near the cloud 2; continue this action slowly, until the clouds, which are furnished with two small brass balls, are within an inch of each other, when a beautiful flash, strongly resembling lightning in miniature, will pass from one cloud to the other, restoring an electrical equilibrium.

45. If the jar (I) be put behind, and the cloud 2 removed, a vessel, communicating by means of a wire with the outside of the jar, may be swam in water under the remaining cloud; the mast being made of separate pieces, and but slightly joined together. When the cloud is passed over the vessel, the mast will be struck, and shattered to pieces.

These experiments will explain the manner in which accidents occur from the discharge of electric clouds, and show the cause of thunder and lightning.

THUNDER AND LIGHTNING.

46. The following interesting explanation is given by Brand of the cause of thunder continuing to be heard for a long time after the discharge of the electric fluid:—"The discharge of electricity in a thunder storm is sometimes only from cloud to cloud; sometimes from the earth to the clouds; and sometimes from the clouds to the earth, as one or other may be positive or negative. When aqueous vapor is condensed, the clouds formed are usually more or less electrical; and the earth below them being brought into an opposite state, by induction, a discharge takes place when the clouds approach within a certain distance, constituting lightning; and the undulation of the air, produced by the discharge, is the cause of thunder, which is more or less intense, and of longer or shorter duration, according to the quantity of air acted upon, and the distance of the place where the report is heard from the point of the discharge." It may not be uninteresting to give a further illustration of this idea. The electric fluid travels so amazingly rapid, that it is found impossible to calculate its rapidity. It has been made to travel along a wire, four miles in length, one end of which being brought near the same spot from which the other proceeded, the exact time of the discharge at both ends could be seen at once, and not the slightest difference has been perceived. The spark passed from the end of the wire, after traversing a distance of four miles, at the same instant that it was given off by a leyden jar to the other end! Sound does not travel so quickly, but moves at the rate of twelve miles in a minute. Therefore, supposing the lightning to pass through a space of some miles instantaneously, the explosion will be *heard* first from that part of the air agitated nearest to the spectator; it will gradually come from the more distant parts of the course of the electricity, and, last of all, it will be heard from the remote extremity. The different degrees of the agitation of the air, and likewise the difference of the distance, will account for the different intensities of the sound, and its apparent reverberations and changes.

47. A person may calculate the distance of the point from which the lightning is discharged, by counting the number of seconds which elapse between the moment when the flash of lightning is first perceived, and when the thunder is heard, allowing five seconds for every mile.

SAFETY IN A THUNDER STORM.

48. Sir Humphrey Davy states in his "Elements," that in a violent thunder storm, when the sound instantly succeeds the flash, the persons who witness the circumstance are in some danger; when the interval is a quarter of a minute, they are secure. The safest situation is the middle of a room, at a distance from the chimney, and standing upon a woolen rug, which is a non-conductor. Blankets and feathers being non-conductors, a bed is a place of comparative safety, provided the bell-wires are not too near, as they are almost always melted in houses struck by lightning. When out of doors, it is dangerous to take shelter under trees, as the lightning often rends off the branches; the safest situation is within some yards of the trunks, and upon the dryest spot that can be found.

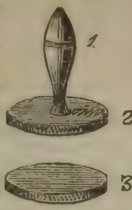
ELECTRIFIED SHEET OF PAPER.

49. Take a sheet of letter paper, and divide it into two portions; dry them both at the fire, and laying one over the other, rub them in one direction with a piece of Indian rubber. They will, by this means, become oppositely electrified, and attract each other; if separated in a dark room, a spark will be perceived. This is a simple *electrophorus*, and well illustrates how easily the electric fluid can be excited. Unless the paper be dry, the experiment will not succeed; and it should, therefore, be dried just before it is used.

THE ELECTROPHORUS.

50. This instrument, which may be easily constructed, will illustrate many of the experiments mentioned in this work, and is exceedingly useful in the laboratory, where an electrical machine would be in danger of being broken. To construct an electrophorus, the following method is adopted:—Mix together equal parts of Venice turpentine, resin, and shell-lac, and expose the whole in a crucible, or pipkin, to the fire, until they are thoroughly melted and combined. Pour the mixture into a hoop, about a foot in diameter, placed upon a slab of stone, so that when it cools it can easily be removed in a cake; let it be about half an inch thick, and cover the upper part with tin foil. Then, turn this side underneath, in or-

der that the upper side may be smooth, and place on the resin a polished plate of metal, or disk of wood, covered with tin foil, supported by a glass handle, rising from the centre; the metal, or disk of tin foil, should be circular, but rather smaller than the resin, and both should be rounded at the edges. This constitutes an exceedingly useful machine. The annexed diagram is the representation of an electrophorus, about twenty sparks from the upper conductor of which is sufficient to charge a small Leyden phial. 1. Glass handle; 2, disk of brass, or of wood, covered with tin foil; 3, cake of resin.



TO CHARGE THE ELECTROPHORUS.

51. When it is wished to charge the electrophorus, in order to electrify any substance, the following plan is to be pursued:—Rub the surface of the resin with a piece of dry fur (such as a portion of rabbit-skin,) and place the metal plate on the disk of resin. Upon raising it, it will be found very feebly electrical; replace it, touch it with the finger, and again lift it off by its handle, and it will give a spark of positive electricity. This process may be repeated very often, without fresh excitation, and the electricity may be given off to any substance by the disk (2) represented in the wood cut. It may also be accumulated in a Leyden jar, when a powerful charge is required; and thus the electrophorus may, to a certain extent, be made to supersede the electrical machine. It can be used for all the experiments described in this work.

THE ELECTRIC SPARK.

52. When the knuckle is presented to the prime conductor of an electrical machine, or to the edge of the metal plate of the electrophorus, after they have been charged with electricity, a spark is given out, and a sharp cracking noise heard. The spark is of a blueish color in the atmosphere, in its ordinary state, but in a glass vessel, containing condensed air, it is white; in rarified air, it is of a reddish tinge; and in a good vacuum, under a receiver, it is of a purple hue, very faintly visible. The electric spark is supposed to be occasioned by the sudden compression of the air, which occasions a degree of heat, sufficient to inflame spirits of wine; but some substances cannot be ignited by it, until it has passed *through water*, when the effect can be produced.

The light and noise which follow the discharge of an electrified body is an illustration of thunder and lightning. When, however, electricity is given off from sharp points, it is not accompanied by noise.

TO CONSTRUCT A CHEAP GALVANIC PILE.

53. To exhibit experiments in Galvanism, on a small scale, a pile may be formed at a very trifling expense, as follows:—Procure about twenty penny-pieces (if worn smooth, so much the better), or get some sheet copper, cut circular, and of a large diameter, and the same number of similar pieces of zinc. The latter may be formed by the experimenter himself; being very easily melted, it may be cast in a mould, like lead, or it may be procured in a sheet, and cut, similar to the copper. Then provide the same number of pieces of cloth, which must be soaked in a solution of common salt water; or, what is better, a liquid composed of one part of sulphuric acid, two of nitric acid, and sixty of water. After this is done, place one of the pieces of zinc in a tea-saucer, and on it put one of the pennies, or pieces of sheet-copper; on this place a piece of cloth, and so continue making the pile—zinc, copper, cloth—zinc, copper, cloth—until they are all piled on one another; taking care to observe the same arrangement throughout. The piece on the top, which will be a penny, should have a copper wire, which, for some experiments, should be tipped with platinum wire, soldered to it, and the lower piece, which will be zinc, should be treated in the same manner. From the ends of these wires a stream of the Galvanic fluid will constantly issue, until all the acid is absorbed from the pieces of cloth; and although the apparatus is on a very small scale, a variety of exceedingly interesting experiments may be performed with it. When completed, the pile will appear as represented in the accompanying cut.

As it is necessary to have at least twenty or thirty pieces of copper and zinc, in order to produc a good stream of Galvanism, and as the pile is inconvenient when made too high, it is advisable to form a number of small piles in a dish, and connect them at the top and bottom by wires, or plates of metal, as represented in the figure. A strong Galvanic power may be thus obtained, without the inconvenience just mentioned.

54. Where the Galvanic pile is not divided, as was before mentioned, in the last experiment, the method usually adopted to support it steadily is, to fix into the piece of wood, on which the pile is formed, three rods of wood or glass, at three equi-distant points. Down these rods may slide a piece of wood, for the purpose of keeping by its pressure the different parts of the pile in contact. The figure is intended to represent this top; the circle in the centre shows the situation of the pile; the three small holes in the rim are for the reception of the rods.

55. The zinc plates in the voltaic pile become oxydized, or rusted, after being used a certain time, and then the Galvanic action ceases; but they may be cleaned by being put into dilute muriatic acid, by which the oxide is dissolved. It is advisable, when the voltaic apparatus is not to be used for some time, to take it down, by which means the zinc plates will be prevented wearing out too fast. The larger the zinc and copper plates are, the more powerful will be the

Galvanic action; and it is better, therefore, to obtain sheet zinc and copper, and cut it, than to use penny-pieces, and zinc of a smaller size.

EXPERIMENTS IN GALVANISM.

To prove water inflammable—To make a cheap Galvanic battery—Chemical decomposition by Galvanism—Galvanic shock described and illustrated—Change of color by Galvanism.

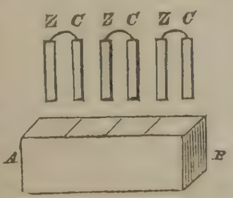
WATER INFLAMMABLE.

56. Water is a compound of two gases, and by means of the Galvanic pile just described, may be resolved into its elements. In the following figure is represented the arrangement that may be employed for the purpose. A glass tube must be filled with water, having the ends closed with corks; *d* and *e* are wires, one of them coming from the top of the pile, and the other from the bottom of it. The wires pass through the corks, and in the tube their ends, *c*, *c*, approach to within a quarter of an inch of each other. The pile for this purpose must be formed of at least fifty or sixty plates. After some time, the end of the wire connected with the zinc, or positive end of the pile will become oxidized, if formed of iron, or other oxidable metal; while from the point of the other wire, coming from the copper, a stream of small bubbles of gas will rise, which is hydrogen, and is one of the elements of water. The water displaced by the gas will ooze out round the corks, and after a time the tube will be filled with gas.

57. The gas obtained by the last experiment may be proved to be inflammable, by pulling out the cork at one end of the tube, after holding it upright, and applying a match, when the gas will ignite; it must be done quickly, and it is advisable to wrap a handkerchief round the tube, as the explosion often breaks it. Thus it will be seen that water, which is the great antagonist to fire, is really formed principally of an inflammable gas; and if, instead of using iron wires, platinum is employed, oxygen, the other element of water, may be obtained. It will, however, be mixed with the hydrogen if thus procured, and the mixture is very explosive.

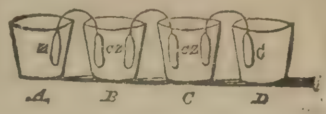
TO MAKE A CHEAP GALVANIC BATTERY.

58. To produce any powerful effect by Galvanism, it is necessary to have a battery, which is usually employed in this form, where a plate of zinc and a plate of copper are attached to each other, and immersed in a weak acid solution, in an earthen or wooen trough (A B), divided into regular compartments, as in the figure.



When a number of these troughs are connected together, so that a stream of Galvanism from the whole of them may be made to issue from the points of two wires in the usual way, the most powerful effects can be produced; such as melting metals, and decomposing compound substances.

59. Galvanism may also be excited, by filling a number of glasses, A B C D, with dilute acid and placing into each a plate of zinc and copper, Z C,



not in contact, but connecting the adjoining pieces of the different glasses by wires, following the same arrangement throughout of zinc, copper, zinc, copper, and so on; the zinc of one glass being joined to the copper of the adjacent one. As both sides of the metal in this apparatus are exposed to the acid, a stream of Galvanism is produced, which is very powerful, considering the small number of plates. This form of battery is, however, not much in use now.

CHEMICAL DECOMPOSITION BY GALVANISM.

60. Place *a drop* of the following solution upon a small piece of glass, or on a piece of writing paper, and the platinum extremites of the wires of the Galvanic pile must then be placed in the drop, but not allowed to touch each other. The electricity, or Galvanic fluid, is developed as the acid fluid in the cloth acts upon the zinc, accumulating in one of the wires, and passing to the other; the materials in the solution being affected as it passes through them, and decomposed.

MATERIALS USED.	PRODUCTS.
61. Sulphate of soda, composed of sulphuric acid and soda resting on paper, dipped in solution of cabbage, and dried.	61. The acid accumulates at one wire, and reddens the paper, the alkali at the other, and turns it green.
62. Iodine of potassium, composed of iodine and potassium, mixed with a little starch.	62. The iodine is immediately separated, and forms a blue compound with the starch.
63. Acetate of lead (common sugar of lead.)	63. Metallic lead is deposited in small crystals.
64. Sulphate of copper.	64. Metallic copper is deposited in the same manner as the lead.

GALVANIC SHOCK.

65. Moisten the hands with salt and water, and hold one wire of the pile in each hand; the Galvanic fluid will then be felt to enter the hand and pass through the body, from one wire to the other. When the apparatus is large, the shock is exceedingly powerful and painful; but performed with a small pile, it produces rather a pleasant sensation than otherwise, which does not pass beyond the fingers or wrists. It is necessary to moisten the hands, because the skin, in a dry state, is scarcely pervious to electricity of Galvanism, of such weak intensity as that procured from the pile.

66. If a large battery is employed, the wires may be placed in separate basins of water; and then, on dipping the fingers of each hand into the basins, a smart shock is experienced; a peculiar aching, accompanied with trembling, is felt up the arms, and, with a strong battery, the shock is experienced as high as the shoulders.

67. A peculiar taste is perceived, if a slight shock be given to the tongue. To perform this experiment, place a shilling, or piece of silver,

under the tongue, and place a piece of zinc upon it, so that the metals do not touch each other. On bringing the edges of the two metals into contact, or making a connection between them by means of a piece of wire, a slight flash will often be perceived, even if the eyes are open, and a peculiar taste will be experienced. If, instead of silver, a more oxidable metal, such as copper, is employed, the taste will be acid; but with the silver, it will be rather alkaline, something like the taste of a weak solution of soda.

CHANGE OF COLOR BY GALVANISM.

68. Put a teasoonful of sulphate of soda into a cup, and dissolve it in hot water; pour a little cabbage blue into the solution (see experiment 130,) and put a portion into two glasses, connecting them (as represented in the figure below,) by a piece of linen or cotton cloth, previously moistened in the same solution. On putting one of the wires of the Galvanic pile into each glass, the acid accumulates in one, turning the blue to a red, and the alkali in the other, rendering it green. If the wires be now reversed, the acid accumulates eventually in the glass where the alkali appeared, while the alkali passes to the glass where the acid was.

MAGNETISM.

EXPERIMENTS IN MAGNETISM—To make artificial magnets—Ditto from a poker—Magnetic attraction and repulsion—Effect of a magnet on a watch—Peculiarity of magnetical attraction—Polarity of the magnet—To make a magnet by Galvanism—Effect of a current of electricity on a magnet.

TO MAKE ARTIFCIAL MAGNETS.

69. The following process may be adopted to magnetise small bars of steel, which may be thus made to become magnets of considerable power without the aid of a magnet:—Take a poker, and support it upright between the knees, having previously tied to it, with a piece of silk, as in the annexed figure, at *a*, the piece of steel to be magnetised. Hold this part with the left hand, and grasp the tongs with the right, a little below the middle, holding them in a vertical position; then let the steel bar be rubbed with the lower end of the tongs, from the bottom to the top, about a dozen times on each side. By this means, sufficient magnetic power may be given to the bar to enable it to lift small pieces of iron and steel. The lower part of the bar *a*, should be marked before it is tied to the poker, in order to distinguish its poles when it is taken off; the end pointing to the earth being the north pole, and the upper end the south.

70. A magnet may be made by rubbing a piece of hard steel with a natural or artificial magnet. Take a common sewing needle, and pass the north pole of a magnet from the eye to the point, pressing it gently in so doing. After reaching the end of the needle, the magnet must not be passed back again towards the eye, but must be lifted up, and applied again to that end, the friction being always in the same direction. After repeating this a few times, the needle will become magnetised, and attract iron-filing the same as the magnet from which it has derived its power.

71. A poker may be made magnetical, by supporting it in a position slightly inclined to the perpendicular, the lower end pointing to the north, and striking it sharply a few times with a hammer. This is a simple and expeditious way of procuring an artificial magnet, and may readily be adopted. Bars of tempered steel may be magnetised in this way, and the better the steel the more permanent will be the magnet.

TO SHOW MAGNETIC REPULSION AND ATTRACTION.

72. The repulsion of both poles of magnetised bars of iron is well illustrated by the following experiment. If we suspend two short pieces of iron wire (N S, N S) by threads, they will hang in contact in a vertical position. If the north pole of a magnet (N) be now brought to a moderate distance from the wires, they will recede from each other, as in Fig. 1. The ends S S, being made south poles by indication from the north pole (N,) will repel each other, and so will the north poles, N N. This separation of the wires will increase as the magnet A approaches nearer them; but there will be a particular distance at which the attractive force of N overcomes the repulsive force of the poles S S, and causes the wires to converge, as in Fig. 2; the north poles, N N, still exhibit their mutual repulsion.

FIG. 1.

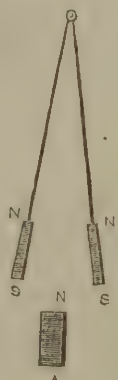
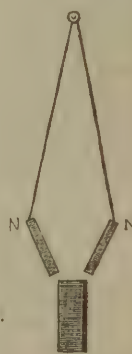


FIG. 2.



EFFECT OF MAGNETISM ON A WATCH.

73. The following experiment, if well performed, is calculated to excite a good deal of astonishment amongst persons who are not acquainted with the powers of the magnet. Request the loan of a watch from some person, and ask if it will go when laid on the table. The answer, of course, will be in the affirmative, and the experimenter can then inform the company

that he possesses the power of commanding the watch to stop, or go, at his pleasure. For this purpose, a magnet must be fixed underneath the top of the table, and a mark made on the table immediately above it; then if the watch be laid on this spot, the magnet will attract the steel balance-wheel, and stop the watch. Directly the magnet is moved, the watch will again go on, and thus it may be made to stop or go, at the pleasure of the experimenter. More surprise will be created if, after having removed the magnet from under the table, another person be requested to try whether his placing it on the table will have any effect, which, of course, will not be the case while the magnet is removed.

This experiment is a very old one, but it illustrates how easily chronometers may be affected by accidental causes; and sometimes the mariner's compass itself loses its power, in consequence of superior magnetic influence, occasioned by having particular substances on board a ship.

TO SHOW MAGNETIC ATTRACTION.

74. If a magnet be brought into contact with some iron-filings, they will adhere to it. The filings are strongly attracted to each pole, but none of them to the centre of the bar. It appears, from this circumstance, that the magnetic power resides chiefly in the poles, and that there is a part of the magnet, generally midway between them, where little or no attractive power is exerted.

75. The north or south pole of one magnet repels the north or south pole of another, just as bodies similarly electrified repel each other. If a magnet be dipped in iron-filings, they will immediately become attached to one end. Supposing this to be the north pole, each of the ends of the filings, not in contact with the magnet, will become north poles; while the ends in contact will, by induction, become south poles. Both of these will have a tendency to repel each other, and the filings will, therefore, stand on the magnet. The ends of the filings in contact cannot repel each other, because they are so strongly attracted by the pole of the magnet; but at their other ends, where this force is not exerted, they do repel each other, showing that they are in the same magnetic state.

POLARITY OF THE MAGNET.

76. If a piece of steel, that has been rendered magnetic, be supported so that it can turn freely, it is found to point with one end to the north, and the other to the south (see Introduction.) This property may be pleasingly illustrated, by tying a magnetised piece of steel round its centre with a piece of sewing silk, and supporting it from a stand, as the pith balls are supported in a previous experiment. Another method is, to place a magnet on a piece of cork swimming in a basin of water. If the cork be placed in the centre of the basin, so that it is not attracted by the sides, the magnet will be found to turn due north and south, the same as the mariner's compass, which in case of accident at sea, it might be made to supply the place of.

HOW TO MAKE A MAGNET BY GALVANISM.

77. As mentioned in the Introduction, Galvanism is capable of forming magnes out of common steel. To effect this, make a connection between the poles of an excited battery with the two ends of a wire formed into a spiral coil, by bending common bonnet wire closely round a cylinder, or tube, of about an inch in diameter; into this coil introduce a needle, or piece of steel wire, laying it lengthways down the circles of the coil. In a few minutes after the electric fluid has passed through the spiral wire, and, consequently, round the needle or wire, the latter will be found to be strongly magnetised, and to possess all the properties of a strong magnet.

78. The same effect may be produced by passing a charge through this spiral coil from an electrical battery.

EFFECT OF A CURRENT OF ELECTRICITY ON A MAGNET.

79. If a current of electricity be made to pass along a wire, under which, in a line with it, a compass is placed, it will be found that the needle will no longer point north and south, but will take a direction nearly across the current, and point almost east and west. This fact has led philosophers to believe, that there are constant currents of electricity passing east and west across the earth, and which, therefore, cause the needle uniformly to point to the north.

CHEMISTRY.

Introduction to the science of Chemistry—Chemical affinity explained and illustrated—The effects it produces—Difference between an "element" and a "compound"—The laws of chemical combination explained—Wonderful effects of these laws—Production of poisons from harmless elements—change of color from combination—Change of bulk from ditto—Crystallization—The atomic theory explained.

80. There are no experiments more pleasing, more instructive, or more easily performed, than those which illustrate the leading principles of the science of Chemistry; and as a knowledge of them may frequently be of eminent service in preventing dangerous accidents, and of great use in many little domestic operations, we have made a numerous collection of the more pleasing and entertaining, and arranged them so that they illustrate all the leading facts in a simple manner. To perform them, it is not necessary to purchase expensive apparatus; for indeed, the whole of them may be illustrated for a few shillings, and the more simple the apparatus, the less danger there is of the experiments failing. Sir Humphrey Davey taught himself chemistry with apparatus, that did not cost him more than a few shillings! and the student who wishes to perform the experiments which follow need not, therefore, fear that the means of doing so are beyond his reach. The best way to begin it is to purchase the smallest quantity of the chemicals that can be obtained; for an experiment may, in general, be tried just as well with a small, as with a large quantity; and if it is obtained pure, from a good operative chemist's, the less that is used the better. Then for apparatus, a few slips of *common window glass*, which may be obtained at any glazier's for a few pence, will answer every purpose. Chemical mixtures, of all kinds, may be made on a slip, by adding two or three drops of the liquids together, and the effect will be seen quite as well as if they were mixed

in greater quantities, in a large vessel. Crystalization may also be beautifully illustrated in this way; and, indeed, nearly all the experiments may be thus performed, so that the young student, with a little ingenuity, may fit up a laboratory for a few pence! This economical plan of proceeding has been acted upon with great success in Edinburgh, where large classes of young gentlemen and ladies have been taught chemistry on this method, by Dr. Reid.

Having thus stated the manner in which the following experiments may be performed, we shall proceed to describe the principal facts they are intended to illustrate. These are, the effects that result from the different degrees of affinity which different substances have for each other, and the changes produced by combination.

81. *Chemical Affinity* is attraction of a peculiar kind. The attraction of gravitation exerts its influence on all bodies; but chemical attraction, or affinity, exists only between particular substances. It is described as "that tendency to unite, which many bodies, possessing different qualities, exert towards each other." The principle will be better understood by the experiments which follow, than by a mere description, and to them therefore, the student is referred; but there are several interesting particulars connected with the subject, which it is necessary should be understood before the experiments are performed.

82. The earth, and the various substances, animate and inanimate, that are found upon it, however diversified in their appearance, and different in their sensible qualities, are all formed out of a few simple elements, which, combining together in different proportions, produce the vast variety of animals, vegetables, and minerals, with which we are acquainted. Thus, two or more elements, in consequence of the affinity they have for each other, will combine and form a particular compound; and this compound, having an affinity or liking for some other compound body, or for an element, unites with it, and produces another substance; by this means it will be seen, that everything on the earth can be formed out of a few simple elementary substances, when they enter into combination.

82. The difference between an *element* and a *compound* is this: an element is something that is not formed by the combination of other substances, while a compound, as the word implies, is a compound of two or more simple substances; a something that is formed by the combination of some of the elements. Thus for instance, lead is called a simple substance, because no means have as yet been discovered by which we can show that it is formed out of any thing else; but we can prove that the preparation called *red lead* is a compound, because, on subjecting it to a certain process, we can separate it into pure lead and oxygen, which are both simple substances. We call lead, therefore, in a state of purity, an element, and its oxide, or red lead a compound. There are only fifty-four elements in nature, but the number of compounds is innumerable.

84. The cause which produces these combinations is termed *chemical affinity*. The word "affinity" does not convey the exact meaning it implies; the word "attraction" will better explain how the power operates. For instance, ammonia (an alkali) has a strong affinity, or is strongly attracted to unite with oil; but it has a a stronger affinity for any of the acids, or, in other words, they attract it more powerfully than the oil. It will happen, consequently, that if oil and ammonia are brought into close contact with each other, by being mixed together, that they will *chemically combine*, and form a compound body, which in fact, is a kind of soap; but as the ammonia has a stronger affinity for an acid than for the oil, it will happen, that if we mix a little sulphuric acid with the soapy mixture, that the ammonia will be attracted *from* the oil, and chemically combine *with* the acid. (See experiment 106.) In this case, we have an illustration of what is meant by the term affinity, and the manner in which it operates. It is, indeed, merely a word used to express the degree of attraction, or as it has been called the "liking," which one substance has for another; and by virtue of which, when allowed to mix together, they will combine chemically. According to the intensity of the attraction or affinity, so will be the force with which the bodies will combine, and with which they will draw the substance they are most strongly attracted to from any other substance with which it may be in combination.

85. Chemistry is the science which teaches the laws that regulate this peculiar kind of attraction; and the best chemist is he who knows most perfectly the different degrees of affinity which bodies have for each other. As there is no kind of knowledge more practically useful than chemistry, it is hoped that the illustrations of some of the leading principles now given may be the means of directing the young student's attention more particularly to the science.

Chemical attraction differs from general attraction, or gravity, in a most important particular. It is an effect which takes place only between the *particles* of which all bodies are composed; it does not act upon masses, and, consequently, before its influence can be excited, the particles must be brought into close contact with each other. Some bodies do not show the affinity they have for each other, unless they are even mixed as liquids, or have some liquid added to them. If we mix what forms a very pleasant kind of drink in the summer time, bicarbonate of of soda and Tartaric acid, together, in the *dry* state, they will remain as a *mechanical* mixture only, the same as if we were to mix a quantity of bran and flour together; but if we add a little water, a violent effervescence takes place, the particles have then been brought close enough for their affinities to come into action, and a chemical compound is the result. The same principle may be illustrated, by a simple experiment, with quicksilver; though the attraction, in this case, is different to chemical affinity. If we place two globules on the table, a little distance apart, they will not attract each other with sufficient force to be drawn together; but if they are gradually pushed closer to each other, when they have passed a certain limit, they suddenly fly together and form one globule. It is necessary, therefore, in order to produce a combination, that

the two should be brought close to each other; the attraction will not show itself at a distance; and this is the case with chemical attraction. It may be regarded, therefore, as a law of chemical combination, that as affinity is a power exerted only by *particles* of matter upon each other, *they must be brought into immediate contact, before any effect can be produced.*

86. Another rule to be remembered is, that *the affinity of a body for different substances varies in intensity.* If the affinity of ammonia for oil be represented by the figure 5, its affinity for the acids will be equal to 10; and, consequently, its tendency to combine with them will be twice that with which it is urged to unite with the oil. Therefore, a substance, for which a body has the strongest affinity, will combine with it in preference to combining with any other. Many examples might be given of this fact. Potassium, for instance, has so powerful an affinity for the element called oxygen, that it will separate it from any other element with which it may be united, and will burst into flame when thrown upon water.

87. In most works on chemistry, tables of the degrees of affinity of a body for different substances are given, showing what compounds it will decompose, by abstracting the substance to which it is particularly attracted. It may be stated as a general rule, that a body which has the strongest affinity for another substance will separate it from any combination it may have formed: this, however, will not hold true in all cases. It was formerly supposed, that a compound body could never be composed by a substance having a weaker affinity for either of the constituents than they had for each other; but it has since been found that such an event can take place, and it may be proved by experiment 99 where a body, having a weak affinity for a substance, separates it from another body, for which it has a more powerful affinity. The circumstance may be explained, by supposing that the intensity of the action between any two bodies depends on their *quantity*, as well as on the peculiar affinity of the atoms individually for each other; and consequently, that a large quantity of any substance, of weak affinity, will overcome the affinity of a smaller quantity, even though it has generally a stronger affinity for a substance than that by which it is subdued.

We must now proceed to describe the effects that are produced when bodies combine together chemically. When this takes place, certain changes are produced in them, by which their appearance, and sensible qualities, are entirely altered. The "laws of combination," which cause these changes are exceedingly simple, and few in number; yet they are capable of producing an extraordinary variety of effects. The experiments which follow will illustrate these laws; and the following particulars will, therefore, be useful in enabling the student to understand the manner in which they operate.

88. The first important fact to be noticed is, that *when two substances combine, the compound they form is always different in its nature to themselves.* Two bodies, decidedly poisonous, when combined chemically, may produce a compound, not merely uninjurious, but even necessary to our existence! This fact is strikingly illustrated in the combinations of the two elements called oxygen and nitrogen. For example:—

The Atmosphere is a compound of	Nitrogen 4	Oxygen 1.
Nitrous Oxide (laughing gas)	Nitrogen 2	Oxygen 1.
Nitric Acid (aquafortis)	Nitrogen 2	Oxygen 5.

Thus it will be seen, that the same elements which, when mixed together in the proportions first mentioned, produce the air we breathe, form one of the most active and destructive poisons, when combined in the quantities necessary to produce nitric acid; for this acid and the air, it will be seen, are both formed from the same elements, only the proportions in which they are combined are different. In the combinations of the element called carbon, or charcoal, we have another striking example of the different forms one substance can assume. Who would believe that a brilliant diamond, and a piece of common charcoal, are the same material, only in different forms? Yet such is the case; and the chemist has the power, by exposing the diamond to a great heat in oxygen gas, of reducing it to the state of charcoal. This circumstance may appear very extraordinary, but it is not more wonderful than that a piece of lump sugar may be converted into carbon. We have shewn, in the experiments which follow (experiment 115), the means by which this can be accomplished; and it is, therefore unnecessary to allude to it more particularly.

A familiar example of the fact that two bodies, actively poisonous in their natural state, may produce a substance, when combined, that shall be perfectly innoxious, is seen in our common table salt. This is composed of muriatic acid and soda. The muriatic acid, taken internally, causes much agony, and ultimate death; and the caustic alkali (the soda), would produce effects very similar; yet when combined together, they produce a substance ranking amongst the first necessaries of life; for, without common salt, it would be almost impossible to maintain health. As an example of poisons being produced from the combination of substances, which, in their natural state, are not injurious, we may instance the poisons which are formed by animals and vegetables. The dreaded worali—the poison used by the Indians—and the pestiferous and destructive upas, which is produced from the tree of that name, and to the influence of either of which animals cannot be exposed without the loss of life, are formed from the same elements as those which produce the luxurious fruits, and the wonderful variety of beautiful flowers that exist in the countries where these poisons are found.— In like manner, the elementary substances that form the flesh of the deer and oxen, upon which man finds subsistence, are the same as those from which the deadly poison of the rattlesnake is produced, or the no less dreaded virus of canine animals in a state of hydrophobia. Thus it will be seen how nature, out of a few simple elements, is able to produce such a wonderful variety of substances, whether the result of organization, or producee from the mineral kingdom.

89. *Change of Color* is another circumstance that frequently attends chemical combination. The most beautiful colors may be formed, and destroyed again, by means of a drop or two of

some liquids, when added to others; and few of the experiments will probably be more interesting than those which are given to illustrate this phenomenon.

90. *Change of bulk* is another event, of frequent occurrence, when bodies combine. Two liquids, on being mixed together, may become solid; and two solids, under similar circumstances, may form a liquid. These facts have been called "chemical miracles;" but, indeed, there is nothing more wonderful in the circumstance than in the other beautiful illustrations of chemical affinity that we have given. All the curious instances of likings and dislikings which substances appear to exhibit towards each other, are equally entertaining; it is only in consequence of some effects not being produced so often as others that we deem them more wonderful.

91. *Crystallization* is another beautiful effect which frequently attends chemical action. Everybody is familiar with the appearance of crystals, and the different forms they exhibit. Thus we have crystals of sugar, in the form of sugar-candy, and crystals of Epsom salts, which are as well known for their different appearance, as for their disagreeable qualities. Both these kind of crystals are as different in form as they are in taste; and many others may be easily called to recollection: yet all these particular forms are occasioned by one simple law of nature, which is another kind of affinity, and causes the particles of various liquids, in cooling, to adhere together, and assume a crystalline shape. In the great operations of nature, crystallization takes place on a grand scale. The Giant's Causeway, in Ireland, and Fingal's Cave, in Scotland, might be mentioned as illustrations; and the crystallization of water, in the form of ice, every one is familiar with. The student may easily imitate some of the phenomena, and, in doing so, will observe how beautifully one general law operates alike on the smallest particles, as well as on masses of immense magnitude. It is merely necessary, in order to procure good crystals, that the liquid should be set on one side to cool gradually, in some place free from dust; and the process may be quickened by dropping a crystal or two into the liquid. From the examples that are given, some knowledge of the variety of forms crystals assume may be derived.

92. Another remarkable fact relating to chemical affinity is, that *the quantity of any substances required to form a particular compound is always the same;* and so long as a body retains its general characteristics, it will always consist of the same elements, united together in the same proportions. For instance, sulphuric acid (oil of vitriol) is always composed of 16 parts, by weight, of sulphur, and 24 of oxygen. No other substances can form sulphuric acid, nor can its own elements produce it, if combined in any other proportions than those just stated. Water, in like manner, is formed of one part, by weight, of hydrogen, and eight of oxygen; and were these elements to unite in any other proportions, some new substance, different from water would be produced. When two or more elements unite to form a compound, the addition or diminution of a small quantity of one, often produces an effect remarkably different to what would have resulted, had the proportions been different. For instance, there is great dissimilarity, both in taste and appearance, between starch and sugar; and yet they are composed of the same elements, and very nearly in the same proportions, as will be seen by the following analysis:—

	Oxygen.	Hydrogen.	Carbon.
Sugar is composed of	40	5	36
Starch	48	13	42

The figures represent the parts of each element, by weight, that form the two substances; so that it will be seen, it is only in consequence of the starch containing a few more particles of its elements than the sugar does, that it differs so materially in its sensible qualities. If we could abstract a few atoms only of the oxygen, hydrogen, and carbon, from the starch, we should convert it into sugar! and in some chemical processes this is really effected. It is in consequence of the beautiful law of nature we have been describing, that chemists are able to tell exactly how much of any substance is contained in any particular compound; for the quantity is always the same, and when it has been once ascertained, it is known always. For instance, sulphate of magnesia (Epsom salts) is formed of sulphuric acid and magnesia. If the latter be added to the acid till effervescence ceases, it will be found, that any magnesia thrown into the solution afterwards will not combine with the acid, but will fall to the bottom of the vessel; thereby showing, that only a certain quantity of magnesia will combine with the acid, to form Epsom salts.

93. Thus it will be seen, that the same great laws which the Creator has established are exemplified as clearly in the most simple experiments, as they are in those grand phenomena of nature that must ever excite the admiration and wonder of every thoughtful observer: and the young student, with a few old glasses for apparatus, and a few pennyworths of chemicals for material, may make himself familiar with the works of the Creator, that, in former times, confounded the profound philosophers. Surely, such pleasure is desirable? It is not merely a gratification of curiosity, but a rational way of exercising those faculties which have been given to us to improve. A person who so employs his time will have the pleasure of knowiug, that he is not merely providing himself with a means of endless amusement, but storing his mind with information of a valuable kind.

94. In describing the different chemical preparations that are to be used in the experiments, we have employed the terms by which they are known to chemists, and added, in a parenthesis, the popular names; thus, "Sulphuric acid (oil of vitriol.") All the chemicals may be obtained at an operative chemist's, by asking for them in the former names; and we again advise those, who perform the experiments only to purchase a small quantity, as a few pennyworths of most of the substances will be quite sufficient.

95. Chemical solution is very different from mere mixture. Solution is a chemical combination between a fluid and any substance that may be dissolved in it; whereas mixture is simply a division of the particles of a body by a mechanical power. Portions of the substance float about in the liquid it is mixed with, but they do not

combine with it; and these portions will, if the mixture remains at rest, fall to the bottom, or rise to the surface, according to their relative specific gravity as compared with that of the fluid. This may be shown by the following experiments:

EXPERIMENTS IN CHEMISTRY.

Combination of sugar of lead in Chemical solution—Apparent anomaly in chemical affinity—How to make soap—To analyse soap—Divisibility of sulphate of iron—Repulsion illustrated—Attraction illustrated—Transformation of sugar into charcoal—Charcoal formed without fire—Lime formed by the breath—Laughing gas described—How to make it—To produce a solid by mixing two liquids—To produce a liquid from two solids—To make infusion of cabbage, and litmus and tumeric papers, for testing—To make lime-water for testing—Change of color by chemical action—To change and destroy the color of flowers—Effect of alkalies and acids on colors—How to make 12 kinds of invisible ink—To make a paper that will not light—Fire in water—Deliquescent salts—Efflorescent salts—To make Epsom salts—To test the purity of water Experiments on crystallization—Influence of light on ditto—How to make mineral baskets—Rapid crystallization—Artificial Quartz—Apparent transformation of iron to copper—Beautiful appearance of hoar frost—To make fusible spoons—Curious property of burning camphor—To test the purity of steel.

EXAMPLES OF CHEMICAL SOLUTION.

96. Put into a glass vessel, containing water, a few grains of sugar of lead, and stir them together with a glass rod; the water will soon become turbid, in consequence of the sugar of lead being insoluble in that fluid, and simply a *mixture* of the particles with the water will take place. If the water be minutely examined, these particles may be seen floating in it; and they will ultimately, if left to themselves, fall to the bottom.

97. If to this milky fluid be now added a few drops of nitric acid, it will instantly become clear and transparent; and now not the most minute portion of the lead will be perceived in it. In the first instance, there was only mixture; in the latter, a perfect *solution*, because the combination of lead and nitric acid is soluble in water, while the sugar of lead is not.

98. If chalk and water be mixed together, the fluid will be turbid; but if a few drops of muriatic acid be added, it will become quite transparent.

APPARENT ANOMALY IN CHEMICAL AFFINITY.

99. It is a general law in chemistry, that one body, having a strong affinity for another, will combine with it, in preference to uniting with any substance of weaker affinity. In the following instances, just the reverse takes place; substances having a weak affinity combine together, in preference to uniting with those for which their affinity is stronger. In the following table, the body first mentioned decomposes a compound of the second and third, named in the same line, although its attraction for the second is inferior to that of the third.

100. *Potash* separates sulphuric acid from barytes.
101. *Lime* separates sulphuric acid from potash.
102. *Nitric acid* separates lime from oxalic acid.
103. *Potash* separates phosphoric acid from lime.
104. *Potash* separates carbonic acid from lime.
105. *Soda* separates sulphuric acid from potash.

It is necessary, in order that the experiments should fully succeed, that a much larger quantity of the first-mentioned substance should be used than the second or third; and the student must not be surprised if the experiment should not be successful.

TO MAKE SOAP—EXAMPLE OF AFFINITY.

106. Pour a little oil into a phial, and add some water to it, when it will be found, in consequence of the oil having no affinity for the water, that they will not combine together, however much they may be shaken; for directly the bottle is still, the oil will rise to the surface. If a small quantity of liquid ammonia (hartshorn) be now introduced gradually into the bottle, and the contents shaken together, they will chemically combine; for the oil and the ammonia have a strong affinity for each other, and when mixed they produce a soapy liquid. This is soluble in water, and, therefore, when the bottle is shaken, the three liquids unite together. This is a very simple, but a very striking experiment, as it clearly illustrates the manner in which chemical affinity separates, and affords a curious instance of the "likings and dislikings" of different bodies.

TO DECOMPOSE SOAP.

107. The oil and the ammonia in the last experiment combine, because there is a strong affinity between them; but if another substance be introduced into the bottle, which has a stronger affinity for one of them than they have for each other, the compound will be decomposed. This may be effected by adding, *very carefully*, a small quantity of sulphuric acid (oil of vitriol) to the mixture. The acid has a stronger affinity for the ammonia than the ammonia has for the oil, and it will, therefore, leave the oil, and combine with the acid. The oil will then swim on the top.

DIVISIBILITY OF SULPHATE OF IRON.

108. Dissolve two grains of sulphate of iron in a quart of water, and add a few drops of this solution to a wine-glassfull of water, into which a few drops of tincture of galls have been placed. The dilute infusion of galls will immediately assume a purplish hue. This shows that every drop of the quart of water, in which the sulphate of iron was dissolved, contains a portion of the salt.

REPULSION.—STEEL AND WATER.

109. If the blade of a well-polished knife be dipped into a basin of cold water, the particles of each of these two bodies do not seem to come in contact with each other; for when the blade is taken out, the water slides off, leaving the blade quite dry, as if it had previously been smeared with any greasy substance.

110. In the same way, if a common sewing needle be laid horizontally on a glass of water, it will not sink, but form a kind of trench on the surface on which it lies, and floats about. This proceeds from the little attraction which exists between the cold water and the polished steel. It is necessary that both the knife, in the last experiment, and also the needle, should be dry and clean; otherwise, the effect will not be produced.

REPULSION.—MERCURY AND GLASS.

111. If a quantity of quicksilver (mercury) be poured into a wine-glass, its upper surface will be *convex*; that is, a kind of trench will be formed all round the mercury, between it and the sides of

the glass. This is in consequence of there being no attraction between the glass and the mercury.

112. An opposite effect may be produced, by pouring a small quantity into a metal cup. In this case, the mercury will appear *concave;* for the attraction of the sides of the vessel for the metal is sufficient to cause it to rise above its level at the edges.

ATTRACTION BETWEEN MERCURY AND GOLD.

113. If a sovereign be rubbed with mercury, it will lose its usual appearance, and appear as if silvered over; the attraction of the gold for the mercury being sufficient to cause a coating of it to remain.

114. When it is wished to remove the silvery appearance, dip the sovereign in a dilute solution of nitric acid, which will entirely take it off. Some rather laughable circumstances have occurred, where persons, having a little quicksilver get loose in their pockets, have been surprised to find their sovereigns, apparently changed to shillings.

The six preceding experiments are not strictly chemical, but they are introduced here for the purpose of illustrating attraction and repulsion.

TO TRANSFORM A PIECE OF LOAF SUGAR INTO A LUMP OF CHARCOAL.

115. It has been previously mentioned, that the diamond has been proved to be only crystalized carbon; it is not generally known that sugar is composed almost entirely of the same substance. Sugar is a vegetable production, and consists principally of charcoal in a peculiar state of combination with water. This may be proved by pouring a little sulphuric acid (oil of vitriol) over a piece of lump sugar, in a saucer, or other vessel. The acid will combine with the water of the sugar, which will, in a few minutes, turn black, and appear precisely like a lump of charcoal. The affinity of sulphuric acid for water is so great, that it attracts it from its chemical union with the sugar.

CHARCOAL FORMED WITHOUT FIRE.

116. If a few small cuttings of wood be placed in a glass, and a little sulphuric acid poured over them, they will become black, like charcoal, from a similar cause to that which produced the effect described in the last experiment.

LIME FORMED BY BREATHING.

117. Pour a little lime water into a tumbler, and breathe into it through a small pipe. Flakes of lime will be immediately formed, and the water will become turbid, in consequence of the breath forced out of the lungs, which contains a great portion of carbonic acid, combining with the lime held in solution in the water.

SINGULAR EFFECTS OF LAUGHING GAS.

118. Protoxide of nitrogen, nitrous oxide, or, as it is more generally termed, laughing gas, is a compound that the young chemist generally desires to procure as soon as possible; and we are induced, therefore, to give the following description of its properties, and of the method to be adopted for obtaining it in a state of purity, although he must not expect to do so without considerable trouble, and some disappointment. Nitrous oxide is a compound of the same elements as those which constitute the atmosphere; but, in consequence of containing a greater quantity of oxygen, its effects upon the human frame, when breathed for a short period, are very surprising. It is not a gas that can be breathed with impunity for any great length of time, yet it can be received into the lungs for a short period without injury. It is termed laughing gas, because its general effect upon persons who respire it is to induce a very strong desire to give way to violent fits of laughter. It does not, however, produce this effect on every individual. Some are made exceedingly melancholy, and others appear desirous of annihilating everything on which they can lay their hands. In general, however, the gas only excites the person who breathes it to laughter. It acts as a powerful stimulant for a time, but, unlike other stimulants, it is not followed by lassitude, or lowness of spirits, unless, while under its influence, the person is excited to excessive muscular exertion. Sir Humphrey Davy made a variety of experiments with this gas. He administered it to various persons, and, indeed, was the first to investigate its properties with any degree of accuracy. Previous to his time, the gas was considered to be unfit for the purpose of respiration, but Davy found that it could be breathed with safety; and in his further experiments on it discovered the singular effects it produces. After a few inspirations of it have been made, it causes a sense of lightness and expansion of the chest, and a pleasurable sensation begins to extend over the whole body; this increases, and is accompanied with a desire to inhale the gas; respiration becomes, therefore, fuller, and is performed with more energy. Exhilation is soon produced; and if the respiration is continued sufficiently long, a crowd of indistinct ideas, often in very singular combinations, pass through the mind; there is an irresistible propensity to laughter, and to muscular exertion and violent efforts are made with alacrity and ease. These effects, after the inspiration has ceased, continue for four or five minutes, or sometimes longer; they gradually subside, and what is not the least singular, the state of the system returns almost immediately to its usual standard. We have frequently administered the gas to others, and have breathed it ourselves; and when this is done in a proper manner, we have never failed to observe or feel the effects above described. There is, however, some difficulty in administering the gas properly to a person who has never taken it before. It must be enclosed in a bladder, fitted with a stopcock; and unless the person inhales it from the bladder without allowing any of the atmosphere to enter his lungs at the same time, the experiment will not succeed. The best way is, to close the nostrils with the left hand, and then, forcing all the air possible from the lungs by a strong respiration, to place the stopcock in your mouth, and so breathe in and out of the bladder, at the same time keeping the nostrils quite closed. If this be done properly, the gas is sure to produce its usual effects. When it is administered to a person, unless he has taken it previously, and is aware of the manner in which it affects him, it is desirable to have some one near to prevent his doing any mischief, in case he should feel so inclined. Self-command is in general entirely lost

for a few minutes, although the individual is perfectly sensible all the time in what a ridiculous manner he is behaving. A bladder capable of holding a few quarts of gas will be large enough, and it is advisable to test the gas by holding a light in some of it before it is taken.

HOW TO MAKE LAUGHING GAS.

119. There are various methods of procuring this gas, but we think our readers will find it best to obtain it from nitrate of ammonia. This should be placed in a glass retort, and exposed to the flame of a spirit lamp. It will soon melt, and shortly afterwards the gas will be evolved. It should be collected in a receiver, placed in a pneumatic trough, and allowed to stand a short time over water, in order to remove any impurities with which it may be contaminated. The nitrate of ammonia, when melted, should only be kept simmering; for if the heat be increased too much, it will cause a slight explosion, and nitric oxide and nitrogen gas will be produced. If it be wished to make a considerable quantity of gas, it will be advisable, on the ground of cheapness, for the operator to prepare the nitrate of ammonia himself. This may be done by pouring diluted nitric acid on carbonate of ammonia, and evaporating the solution till the greater portion of the water is gone.

TO PRODUCE A SOLID FROM TWO LIQUIDS.

120. This surprising effect may be produced by mixing sulphate of magnesia (Epsom salts) with water, until it will dissolve no more, and then pouring into it a saturated solution of caustic potass. In this case, the sulphate of magnesia is decomposed; the sulphuric acid leaves the magnesia, which then combines with the water, and is precipitated in the form of a white powder, while the acid unites with the potass.

121. If a saturated solution of chloride of calcium be mixed with a saturated solution of carbonate of potash, both of which are transparent liquids, the result will be, the formation of an opaque and almost solid mass. Mutual decomposition of the salts takes place; chloride of potassium and carbonate of lime are formed; the latter absorbs the whole of the water of solution, and thus a degree of solidity is produced.

121. If a little nitric acid be added to the mass, it will be converted into a transparent liquid; the insoluble carbonate of lime being converted into the soluble nitrate of lime.

122. If a small quantity of sulphuric acid be dropped into a saturated solution of chloride of calcium, an opaque and nearly solid mass will be produced; as the chloride is decomposed, and sulphate of lime, a very insoluble salt, formed.

123. Dissolve a small quantity of acetate of lead (sugar of lead) in water, about half filling a beer tumbler; mix in another glass the like quantity of bichromate of potass. If the contents of one glass be then poured into the other, a solid compound will be formed, which falls to the bottom of the glass.

124. Make a strong solution of sulphate of magnesia (Epsom salts,) by melting as much as possible in warm water. If a small quantity be poured into a glass, and a little ammonia (hartshorn) added to it, the ammonia will combine with the sulphuric acid, and liberate the magnesia, which will then appear in the glass in a nearly solid state. As both the solution of salts and the ammonia are transparent till mixed, this is a very striking experiment.

TO MAKE TWO SOLIDS FORM A LIQUID.

125. Triturate together, in a wedgewood-ware mortar, half an ounce of sulphate of soda, with the same quantity of acetate of lead, and they will combine together and form a liquid, in consequence of their giving out their waters of crystallization.

126. Mix together nearly equal quantities of carbonate of ammonia and sulphate of copper in a mortar; pulverise them well, and they will form a violet-colored liquid.

127. Triturate together, in a mortar, half an ounce of citric acid, in crystals, with a similar quantity of carbonate of potass. These substances will combine, and become fluid.

128. Put an ounce of sulphate of soda, with the same quantity of nitrate of ammonia, into a mortar, and rub them smartly together with the pestle, when they will both part with their water of crystallization, combine together, and become liquid.

129. Triturate half an ounce of muriate of lime with half an ounce of nitrate of soda: these two substances will operate upon each other, and become liquid like the others.

TO MAKE TEST PAPERS.

130. For the purpose of many of the experiments described, it is necessary to be provided with test papers, for ascertaining when an acid or an alkali is present in any solution. The following directions will enable the experimenter to prepare them himself:—Boil a few leaves of a red cabbage, cut into small pieces, in a small quantity of water, or pour boiling water over them; then strain it into a piece of cloth, and dip into it some slips of blotting, or other thin paper, which must then be allowed to dry, and afterwards dipped again two or three times. These papers are turned of a *red* color when touched by acids, and *green* by alkalies. The liquid itself may be used in many experiments, but it must not be kept too long after it is made.

131. *Litmus paper*, which is turned red when dipped into an acid, may be prepared by boiling litmus in water, and afterwards placing the papers in it, as just described.

132. *Turmeric paper* is a test for alkalies, being changed from a bright yellow to a reddish brown. They may be prepared by pouring a small quantity of boiling water upon some turmeric, and afterwards dipping the papers in it, and drying them. The test papers should be cut into slips, and they will be more handy for use.

TO MAKE LIME WATER.

133. *Lime water* may be formed by putting a small quantity of slacked lime into a bottle of water, and shaking it till dissolved. It is a test for the presence of carbonic acid; and, if left uncovered, will soon absorb it from the atmosphere.

CHANGE OF COLOR BY CHEMICAL ACTION.

134. Infusion of red cabbage (see experiment 130), or almost any vegetable *blue*, will become

red by the addition of sulphuric acid, or any of the common acids.

135. Take a little sulphate of iron, andd issolve it in water; add to it some infusion of oak bark, or infusion of nut-galls, and it will instantly become *black.*

136. To some common writing ink add a little muriatic acid, and the color will immediately be *destroyed.* To this add a little solution of some alkali (ammonia, for instance), and the black color will be *reproduced.*

137. Take a *colorless* solution of sulphate of copper, add to it a little ammonia, and it will become of a beautiful *blue* color.

138. To this mixture add some nitric acid, and the blue color will *disappear.*

139. Add another portion of liquid ammonia, the *blue* color will be reproduced.

140. Take a little of the solution of red cabbage, which is of a *blue* color, and add to it some solution of potass, or soda, or ammonia, when it will become *green.*

141. Add to this mixture sulphuric acid, drop by drop; it will then change to a *blue*, and ultimately to a *red* color.

142. If a little chlorine gas be now passed through the liquid, it will *destroy* all the color, as this is its effect on vegetable matter.

TO CHANGE THE COLOR OF FLOWERS.

143. Get some violets, and place them in a glass jar inverted in a dish of water. Place a metallic vessel, or a common piece of tile, in the jar, and on it put a little sulphur, which is to be ignited. If the violets are exposed to the gas, which is thus formed for a short time, their color will be destroyed, and they will be *blanched.* The same effect may be produced on a variety of other flowers.

144. Hold some of the violets, after the last experiment, in the vapor (muriatic gas), which arises on pouring a little dilute sulphuric acid on common salt; they will then assume a *red color.*

145. Pour a little ammonia (hartshorn) in a bottle, and drop into it another portion of the flowers blanched by the first experiment; they will then be turned to a *bright green.*

146. Put a number of flowers, of any color, and a few blades of grass, or some green leaves, into a bottle containing some chlorine gas, and their color will be immediately destroyed. This is very prettily illustrated, by placing in the bottle a sprig or two of parsley, which, by the action of the chlorine, is rendered quite white.

147. Chloride of lime dissolved in water, with a little of any of the acids added to it, may be employed for this purpose instead of chlorine gas; or even the dry chloride of lime may be used for the same purpose.

PURPLE, GREEN, AND SCARLET, PRODUCED FROM A BLUE COLOR.

148. Place a small quantity of the blue tincture of cabbage in three wine-glasses; to the first, add a little solution of alum, and the color will be changed to *purple.*

149. To the second glass, add a little solution of ammonia, which will render the liquid *bright green.*

150. In the third, place a few drops of muriatic acid, and this will turn the liquid to a beautiful *scarlet.*

These experiments show the effect of a salt, an alkali, and an acid, in changing vegetable colors.

TO SHOW THE EFFECT OF ALKAKIES AND ACIDS ON COLORS.

151. If a slip of turmeric paper, which is of a yellow color, be dipped in ammonia, or any alkaline solution, it will become of a *deep red brown.* If it be dipped in an acid, it will turn quite *red.*

152. A solution of chlorine in water, or a solution of chloride of lime, deprives all vegetables, and vegetable infusions, of their colors.

153. If a slip of tumeric paper be held over a bottle of liquid ammonia (hartshorn), its color will be changed from yellow to brown by the vapor which rises.

154. An addition of a little of any of the acids to the above mixtures will turn them of a beautiful red color.

SYMPATHETIC INKS.

155. Writing with inks of this nature is illegible, unless a chemical change be subsequently effected on them. Many amusing experiments may, therefore, be performed with inks of this description. A letter may be written with common ink, and another with sympathetic ink between the lines of the former. Drawings may also be made, which shall change their appearance: thus a picture, representing a winter scene, may be made to change, and appear like summer, on the application of heat and other reagents; and a variety of similar effects can easily be produced. The following description of the manner of procuring a variety of these inks will afford the student a selection on which he can exercise his ingenuity.

FIRST KIND—SILVER INK.

156. Write with dilute nitrate of silver (lunar caustic), which, when dry, will be entirely invisible; hold the paper over a vessel containing sulphate of ammonia, and the writing will appear very distinct. The letters will shine with the metallic brilliancy of silver.

SECOND KIND—YELLOW INK.

157. Write upon paper with a diluted solution of muriate of copper; when dry, it will not be visible, but on being warmed before the fire, the writing will become of a beautiful yellow color.

THIRD KIND—GREEN INK.

158. Write with a solution of muriate of cobalt, and the writing, while dry, will not be perceptible; but if held before the fire, it will then gradually become visible, and the letters will appear of an elegant green color.

FOURTH KIND—BLUE INK.

159. Write with acetate of cobalt, or with a muriate of cobalt, previously purified from the iron which it generally contains. When the writing has become dry, these letters will also be invisible. Warm the paper a little, and the writing will be restored to a beautiful blue.

FIFTH KIND—ANOTHER BLUE INK.

160. Write with a weak solution of sulphate of iron, and when dry, wash the letters with prus-

siate of potash, by dipping a feather in it, and lightly passing it over them: they will then appear of a beautiful blue.

SIXTH KIND—BROWN INK.

161. If a solution of sulphate of copper be used instead of common ink, and allowed to dry, and the writing be then washed with prussiate of potash, it will appear of a reddish brown.

SEVENTH KIND—DARK INK.

162. Write on paper with a solution of nitrate of bismuth: when this is dry, the writing will be invisible; but if the paper be exposed to sulphuretted hydrogen gas, the words will be distinctly legible.

EIGHTH KIND—BLACK.

163. A letter written with a dilute solution of bismuth becomes, when dry, illegible; but a feather dipped in a solution of sulphuret of potash will instantly blacken the oxide, and revive the writing.

NINTH KIND—BLACK.

164. Write with a solution of nitrate or acetate of lead. When the writing is dry, it will be invisible; then, having prepared a glass decanter, with a little sulphuret of iron strewed over the bottom of it, pour a little very dilute sulphuric acid upon the sulphuret, so as not to wet the mouth of the decanter, and suspend the writing, by means of the glass stopper, within the decanter. By an attention to the paper, the writing will become visible by degrees, as the gas escapes from the bottom of the vessel.

TENTH KIND—BLACK.

165. Write with a weak solution of sulphate of iron, let it dry, and it will be invisible. By dipping a feather in tincture of galls, and drawing the wet feather over the letters, the writing will be restored, and appear black.

ELEVENTH KIND.

166. Mix alum with lemon juice. The letters written with this ink will be invisible till dipped in water.

TWELFTH KIND.

167. A letter written with common milk, or with the juice of an onion, may be deciphered when held before the fire, and the paper is singed.

TO MAKE A PAPER THAT WILL NOT LIGHT.

168. Pulverise a small quantity of gunpowder and alum in a mortar, and dissolve the mixture in water. Paper dipped in this solution, when thoroughly saturated and dried, will not ignite.

FIRE IN WATER.

169. If a few pieces of phosphuret of lime be placed in a tumbler of water, it will be decomposed, and bright flashes of light will dart from the surface of the water, presenting to those who are unacquainted with the cause, a very striking phenomenon.

DELIQUESCENT SALTS.

170. The atmosphere produces two effects, very opposite, on different kinds of salts: some absorb water from it and melt, and are, therefore, termed *deliquescent;* others part with the water they may contain, and become powder, they are efflorescent.

171. If a little carbonate of potash be exposed to the atmosphere, it melts, and in a short time changes to a perfect liquid.

172. If a few crystals of muriate of lime be exposed in a similar manner, they will soon become liquid.

EFFLORESCENT SALTS.

These salts become converted into powder by the action of the air. The following are examples:—

173. Expose some crystals of phosphate of soda, on a sheet of paper, and in a short time they will be converted into a white powder.

174. Common Epsom salts are affected in a similar manner, and they should, therefore, be kept in a close bottle.

175. The same effect is produced on the crystals of sulphate of zinc.

TO MAKE EPSOM SALTS.

176. This well-known medicine (sulphate of magnesia) may be prepared in the following way: Put an ounce of carbonate of magnesia into a tumbler, and pour over it a quantity of water; then add, *carefully*, by degrees, sulphuric acid (oil of vitriol), until effervescence has ceased, when the two substances will have saturated each other, as it is termed by chemists. After this, the liquid must be filtered through blotting paper, and then put in a warm place, so that a portion may evaporate; crystals will then soon form, which, on examination, will be found to be common Epsom salts.

TO TEST THE PURITY OF WATER.

177. Water, in a state of purity, can only be obtained by distillation, or as it falls in the form of rain. From its being able to hold, in solution, so great a variety of substances, it is almost always contaminated with some of them. Spring water becomes impregnated with the various earthy matters through which it runs; and river water is still more impure, in consequence of the many foreign substances that find their way into it. For chemical purposes, where it is essential that the water should be quite pure, it is necessary, therefore, to distil it, by which means the impurities are separated from it. In order to ascertain the general properties of any kind of water, it may be tested in the following manner:—

178. Pour a small quantity of it into a wine-glass, and dip into it a slip of litmus paper, when, if an acid is contained in the liquid, in any quantity, the paper will become red: if the water contains an alkali, the test-paper will become green.

179. The presence of earthy matter may be ascertained by mixing a little soap with water, if much earthy matter is in it, the soap will be curded. This is the reason why it is impossible to form soap-suds with spring water.

180. Evaporate a drop of the water to be tested from a watch-glass. Small rings will appear if it contained only a small portion of impure water; but a crust is seen if it held, in solution, much saline or earthy matter, and the crust has an ochry tint, if iron be present.

EXPERIMENTS ON CRYSTALLIZATION.

181. Into a vessel, containing a solution of nitric acid in water, drop a few small pieces of carbonate of ammonia, as long as any effervescence continues. Put a small quantity of the liquid into a watch-glass, and evaporate a portion of the water by holding the watch-glass over a spirit-lamp for a few minutes; or place it on the hob of the fire-place for a short time. If the glass be afterward removed, and the liquid allowed to cool, very beautiful crystals of nitrate of ammonia will form. This is the salt from which laughing gas is procured (see experiment 118).

182. Moisten the interior of a glass tumbler with muriatic acid, by means of a long feather; and also moisten the inside of another tumbler, in the same way, with liquid ammonia. If the mouths of the glasses be now brought together, the vapors arising from the muriatic acid and the ammonia will combine, and produce white fumes, which will deposit themselves in the form of crystals in the interior of the glasses. This experiment is not always successful.

183. If subcarbonate of potash be added to a solution of nitric acid in water, till effervescence ceases, or the solution is saturated, and a portion of it be afterward evaporated in a watch-glass, or a saucer, very beautiful crystals will immediately form.

184. Melt a little sulphur in an iron table-spoon, and pour it into a wine-glass, of a conical form, that has been moistened slightly. The sulphur will immediately crystallize, and become solid; if the process be watched, the crystals may be observed to shoot across the fluid mass in a very beautiful manner.

185. Melt a small quantity of sulphur, cautiously, in a Florence flask, and after removing it from the spirit-lamp, or flame by which the sulphur has been melted, pour away the liquid that remains when the outer portion has become solid, and the crystallization of the sulphur may then be seen. The mass will form a very pleasing object if taken from the flask.

186. The following experiment is described by Dr. Reid, as a pleasing illustration of metallic crystallization:—Heat a common plate of sheet tin, which is merely iron covered with tin, before the fire, or over a lamp, till it is as warm as may be necessary to cause water dropped upon it to evaporate quickly, with a slight hissing noise. Let the tin with which the iron is coated be then washed with a cloth, well moistened with a mixture composed of water, one ounce, muriatic acid, one drachm, and nitric acid, one drachm. The cold fluid causes the hot tin suddenly to assume the crystalline form; and as the acids act upon the external particles of the tin, and expose those below, the crystalline arrangement is beautifully seen.

187. If a little nitre be dissolved in boiling water, till the water will dissolve no more, and then allowed to cool, crystals, in six-sided prisms, will be formed.

188. Dissolve an ounce of sulphate of soda in two ounces of boiling water. Pour the solution into a wedgewood evaporating dish, or into a saucer, and put it into a warm place. As the water of solution evaporates, the saline matter will crystallize, resuming the same form which the crystals exhibited before being dissolved.

INFLUENCE OF LIGHT ON CRYSTALLIZATION.

189. To show the influence of light on crystallization, place a solution of a salt in a dark room, and, while it remains uncrystallized, let a ray be admitted, and suffered to fall on one side of the vessel containing the solution; crystals will begin to form on *that side*, and the whole will soon form about those produced.

190. *Acetate of lead* and *fluate of lime* assume beautiful appearances, when under the partial influence of light; crystals will grow, as it were, towards the light, and assume various pleasing forms. The camphor jars in druggists' windows show the influence of light. But, although light hastens, it is not in all cases absolutely necessary to crystallization.

ARTIFICIAL MINERAL BASKETS.

191. These pleasing chimney ornaments can easily be manufactured, and the process beautifully illustrates the manner in which crystallization proceeds. Make a solution of sulphate of copper, alum or copperas, by dissolving either of these substances in hot water, and when it begins to cool, suspend in it little wire baskets for about ten minutes. The alum, &c. will immediately form crystals on the wire, in the same way that sugar does when formed into sugar-candy; and baskets, and other ornaments, of the most pleasing and diversified forms, may thus be easily produced.

RAPID CRYSTALLIZATION.

192. Make a strong solution of Glauber's salt in boiling water, in a Florence flask, and, while hot, cork it up; a vacuum will thus be formed by the condensation of the steam above the surface of the solution within the flask, when the solution is perfectly cold. If the cork be now carefully taken out, the whole will begin to crystallize. Should this effect not be immediately produced, drop a crystal of the same salt into it, and it will instantly shoot into crystals, commencing with the crystal so introduced.

ARTIFICIAL QUARTZ.

193. Any solid substance introduced into a saline mixture hastens crystallization; and it is for this reason that the makers of sugar-candy place threads in the liquid sugar, in order that regular masses of crystals may be formed. This property of crystals to deposite themselves about a nucleus, may be shown in a pleasing manner by placing substances of certain forms in solutions of salts. Imitations of certain minerals, or natural crystals, may be thus produced, of very beautiful appearance, and so exact in their resemblance to natural ones, that the difference cannot be discovered without a close examination. They may be formed as follows:—Take a hard cinder (those from a blacksmith's shop, called "clinkers," are the belts), and place it in a hot solution of alum in water, sormed of about half a pound of alum to a pint of water. In a short time it may be taken out of the solution, and the crystals of alum will be found to have deposited themselves about it, in perfect imitation of natural quartz. Weaker solutions succeed better, but they take a longer time to form.

APPARENT TRANSFORMATION OF IRON INTO COPPER.

194. Make a solution of sulpeate of copper (blue vitriol), by dissolving it in water. If a knife, or any other iron instrument, be then dipped in the solution, it will become covered with a coat of copper, and in appearance exactly resemble that metal. The iron has a strong affinity for the copper, and attracts it from the water.

BEAUTIFUL APPEARANCE OF HOAR FROST.

195. Place a sprig of rosemary, or other garden herb in a glass jar, so that when it is inverted the stem may be downwards, and the sprig supported by the sides of the jar. Now put benzoic acid on a piece of iron, hot enough to sublime the acid in the form of a thick white vapor; invert the jar over the iron, and leave the whole untouched until the sprig is covered with the sublimed acid, in the form of a beautiful hoar frost. This is an excellent example of sublimation.

TO MAKE FUSIBLE SPOONS.

196. Melt about four ounces of bismuth, in a crucible, and, when fused, throw in about two ounces and a half of lead, and once and a half of tin. These metals will combine, and form an alloy, which melts at a very low degree of temperature. If some of it is formed into tea-spoons (which may easily be done, by making a mould in clay, or plaster of Paris, from another spoon), the spoons thus made will produce much amusement; for if one of them be placed in hot tea it will melt, and sink to the bottom of the cup, much to the surprise of the person using them; and even if they do not melt, they will bend considerably. They have a bright appearance, and, if made well, will not be easily distinguished from ordinary metal spoons.

CURIOUS PROPERTY OF BURNING CAMPHOR.

197. If a small piece of camphor be ignited at a candle, and then placed in a basin of water, it will not only float and remain in an inflamed state, but will also appear agitated; and in this state will move to and fro on the surface of the water, at the same time emitting a very fragrant smell. If, during the time the camphor is in motion, a drop of oil be let fall from a feather into the basin, the camphor will suddenly stop, as if arrested by something peculiarly attractive. A drop of any kind of grease produces a like effect.

TO TEST THE PURITY OF STEEL.

198. Steel is a compound of iron and charcoal. If, therefore, a drop of nitric acid fall on a piece of it, the part will immediately become black, in consequence of the acid uniting with the iron, and leaving the carbon free. If the acid be dropped on iron, this effect will not be produced; and the comparative goodness of steel may, therefore, be ascertained by this means.

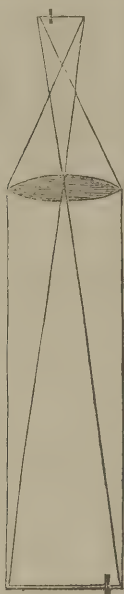
LIGHT AND OPTICS.

Introduction to the science—General description of the properties of light—Principles of optical instruments—The beauty of light—Theories respecting light—The cause of color—Refraction of light—The human eye described—Cause of "short-sight"—Ditto of "long sight"—Position of objects on the retina—Description of the human eye—Properties of a convex lens described—Concave mirror—Plane mirror—Cause of the rainbow.

199. The science of optics is that branch of natural philosophy which treats of the nature of light, the laws by which it is governed, and the effects it is capable of producing. The best summary of the leading facts in the science is given in the "Elements of Physics," by Dr. Arnott, where the following analysis is illustrated at length; and the experiments that follow will demonstrate the leading principles.

200. Light is an emanation from the sun, and other luminous bodies, becoming less intense as it spreads, and which, by falling on other bodies, and being reflected from them to the eye, renders them visible. It moves with great velocity, and in straight lines, where there is no obstacle—leaving shadows where it cannot fall. It passes readily through some bodies, which are, therefore called transparent; but when it enters or leaves their surfaces obliquely, it suffers at them a degree of bending, or refraction, proportioned to the obliquity; and a beam of white light thus refracted or bent, under certain circumstances, is resolved into beams of all the elementary colors, which, however, on being again blended, become the white light as before.

201. Transparent bodies, as glass, may be made of such form as to cause all the rays which pass through them from any given point to bend



and meet again in another point beyond them; the body then, because usually in form resembling a flat bean or beantil, being called a lens; and when the light proceeding from every point of an object placed before a lens is collected in corresponding points behind it, a perfect image of the object is there produced, to be seen on a white screen placed to receive it, or in the air, by looking towards it in a certain direction. Now the most important optical instruments, and even the living eye, are merely arrangements of parts for producing and viewing such an image under a variety of circumstances. When this image is received upon a suitable white surface or screen in a dark room, the arrangement is called, according to minor circumstances, a *camera obscura* a *magic lantern*, or *solar microscope*. And the eye itself is, in fact, but a small camera obscura—of which the pupil is the round opening, or window, before the lens—enabling the mind to judge of external objects by the size, brightness, color, &c, of the very minute, but most perfect images or pictures formed at the back of the eye, on the smooth screen of nerve, called the retina. The art of painting aims at producing, on a larger scale, such a picture, and which, when afterwards held before the eye, and reproducing itself in miniature upon the retina, may excite the same impression as the original objects. When the image beyond a lens, formed as above described, is viewed in the air, by looking at it in a particular direction, then there is exhibited the arrangement of parts constituting the *telescope*, or *common microscope*.

202. Light falling on very smooth or polished surfaces, is reflected so nearly in the order in

which it falls, as to appear to the eye as if coming directly from the objects originally emitting it; and such surfaces are called mirrors. Mirrors may be plane, convex, or concave; and certain forms will produce images by reflection, just as lenses produce them by refraction; so that there are reflecting telescopes, microscopes, &c, as there are refracting instruments of the same kind. Light, again, falling on bodies of rougher or irregular surface, or which have other peculiarities, is so modified as to produce all those phenomena of color and varied brightness seen among natural bodies, and giving them their distinctive characters and beauty.

203. To the presence of light every object in nature owes its appearance of form and color; and we may estimate the important benefits we derive from its presence, by considering how severe a calamity it is to be blind. "The phenomena of light and vision," says Dr. Arnott, "have always been held to constitute a most interesting branch of natural science; whether in regard to the beauty of light, or its utility. The beauty is seen spread over a varied landscape, among the beds of the flower gardens, on the spangled meads, in the plumage of birds, in the clouds around the rising and setting sun, in the circles of the rainbow; and the utility may be judged of by the reflection, that had man been compelled to supply his wants by groping in utter and unchangeable darkness, even if originally created with all the knowledge now existing in the world, he could scarcely have secured his existence for one day. Indeed, the earth, without light would have been an unfit abode even for grubs, generated and living always amidst their food. Eternal night would have been universal death. Light, then, while the beauteous garb of nature, clothing the garden and the meadow, glowing in the ruby, sparkling in the diamond, is also the absolutely necessary medium of communication between living creatures and the universe around them. The rising sun is what converts the wilderness of darkness which night covered, and which, to the young mind not yet aware of the regularity of nature's changes, is so full of horror, into a visible and lovely paradise. No wonder, then, if in early ages of the world, man has often been seen bending the knee before the glorious luminary, and worshipping it as the god of nature. When a mariner, who has been toiling in midnight gloom and tempest, at last perceives the dawn of day, or even the rising of the moon, the waves seem to him less lofty; the wind is only half as fierce; sweet hope beams on him with the light of heaven, and brings gladness to his heart. A man, wherever placed in light, receives by the eye from every object around—from hill and tree, and even a single leaf—nay, from every point, in every object, and at every moment of time—a messenger of light, to tell him what is there, and in what condition. Were he omnipresent, or had he the power of flitting from place to place with the speed of the wind, he could scarcely be more promptly informed. And even in many cases, where distance intervenes not, light can impart at once knowledge, which, by any other conceivable means, could come only tediously, or not at all. For example, when the illuminated countenance is revealing the secret workings of the heart, the tongue would in vain try to speak, even in long phrases, what one smile of friendship or affection can in an instant convey; and had there been no light, man never could have been aware of the miniature world of life and activity which, even in a drop of water, the microscope discovers to him; nor could he have formed any idea of the admirable structure belonging to many minute objects. It is light, again, which gives the telegraph, by which men converse from hill to hill, or across an extent of raging sea; and which, pouring upon the eye through the optic tube, brings intelligence of events passing in the remotest regions of space." (Arnott's Elements of Physics, vol. 2,)

204. In the preceding passage, some of the beneficial effects for which we are indebted to light have been beautifully described; and there is no branch of philosophy better calculated to excite our admiration and reverence for the Creator than the science of optics. But respecting the cause of the phenomena, so striking and so beautiful—respecting the nature of light itself, we are left in as dark a state of ignorance as we are of heat and electricity. Some suppose, and the opinion was supported by the great Sir Isaac Newton, that light consists of particles of solid matter, which are constantly projected from the sun, and other luminous bodies. Others, on the contrary, maintain that it is merely a vibration of a very subtle ether, which effects our organs of sight in the same way as the vibrations of the air produce sound, and affect our organs of hearing.

Whatever is its nature, it moves with a velocity that surpasses comprehension. (See experiment 217.) "What mere assertion," says Sir John Herschel, "will make any man believe that, in one second of time, in one beat of the pendulum of the clock, a ray of light travels over 192,000 miles; and would, therefore, perform the tour of world in less time than a swift runner would make one stride?" Yet such is the fact; the evidence on which it rests is indisputable; and in the experiments which follow, the means, by which a knowledge of the fact was obtained, is stated at length.

205. *Light is the cause of color.* It was formerly supposed that light itself was purely white; but by means of a prism, it may be proved to consist of three, or perhaps four, distinct colors, blended together—viz. red, blue, and yellow, and perhaps violet; which, by their union, form white, and every other color that can present itself to the eye.

Some bodies possess the property of absorbing one or more of the elementary colors, and reflecting the others; and, consequently, a body will appear to be of the colors that would be formed of those which are reflected. And where all the rays are absorbed, and none reflected, the body will appear of no color at all, or, in common language, it will be *black*. For instance, the paper of this book is white, because it reflects all the rays of light which fall on it; and as the three primitive colors form white when mixed together, this is the impression they produce on being reflected to the eye. The type appears black, for reasons precisely opposite. It has the power of absorbing *all* the rays of light, and, consequently,

no color is reflected. The fields appear green, because the red elementary ray is absorbed, and the yellow and blue rays are reflected: these colors, as every schoolboy knows, when mixed together, produce green, and this is the impression made on the eye. The color of every object, excepting those which are black, is occasioned in the same way; the elementary rays that are reflected produce, by their combination, a third color, which is the one impressed upon our organs of vision.

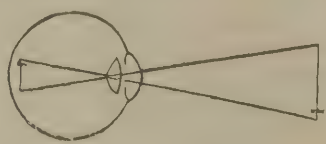
206. *Light is refracted* on passing into a denser medium than that through which it has been traveling; that is to say, it is bent out of its course, and falls in a different spot to what it would have done, had it not passed into a denser medium. Water is a denser medium than the air, and consequently light, in passing from the latter into water, is bent, or refracted: the same effect is likewise produced when it passes from air to glass; and according to the density of the substance, or medium, through which light has to travel, so will it be refracted. Sir Isaac Newton, when experimenting on this subject, found that inflammable bodies refracted light more than others; and finding that the diamond and water, neither of which, in his day, were supposed to be inflammable, possessed the power of refracting light in a high degree, he ventured to predict, that one day they would be found to consist of inflammable materials; and this seeming absurdity has since proved true!

The use of lenses in the telescope and microscope is to refract the rays of light, so that they may meet together at a particular spot, and thus render clearly visible an object that would otherwise be indistinct, in consequence of the rays proceeding from it being too diffused to act upon the organs of vision.

207. *The human eye* is a beautiful illustration of an arrangement to produce this effect. It is in in fact, a natural camera obscura, which is merely a little instrument formed by placing a lens in a hole in front of a small box, through which the light enters, and, being refracted, gives a minute, but very clear and beautiful representation of every object before it (see experiment 227.) The human eye is a globular chamber, of the size of a large walnut, formed externally by a very tough membrane, called, from its hardness, the *sclerotic coat*, or, popularly, the *white of the eye*, in the front of which there is one round opening, or window, named, because of its horny texture, *the cornea*. The chamber is lined with a finer membrane, or web—the *choroid*, which, to ensure the internal darkness of the place, is covered with a *black paint*. This lining at the edge of the round window is bordered by a folded drapery, called the *ciliary processes*, hidden from without by being behind the curious contractile window-curtain, the *iris;* through the central opening of which, or *pupil*, the light enters. Immediately behind the pupil is suspended, by attachments among the ciliary processes, the *crystalline lens*, a double convex most transparent body, of considerable hardness, which so influences the light passing through it from external objects, as to form most perfect images of these objects, in the same way as the camera obscura, on the back wall of the eye, over which the optic nerve, then called the *retina*, is spread as a second lining.

The eye is maintained in its globular condition by a watery liquid, which distends its external coverings, and which in the compartment before the lens, or the *anterior chamber of the eye*, being perfectly limpid, is called the aqueous humor; and in the remainder, or larger *posterior chamber*, being enclosed in a transparent spongy structure, so as to acquire somewhat the appearance of melted glass, is called the *vitreous humor*. The use of the humors of the eye, and of the crystalline lens, is for refracting the rays of light which enter the pupil, and concentrating them on the retina. Here every object is represented in miniature; a landscape of miles in extent is depicted on a little circle, of perhaps less than an inch in diameter: yet every object is so beautifully clear, that we are able to perceive and understand the form and color of the most minute, as well as of objects the most extended.

208. It is indeed, the little picture *on the retina*—not the external objects themselves—that the mind contemplates; and if, in consequence of the light being too much bent in passing through the lens and humors of the eye, it is concentrated or brought to a focus before it reaches the retina, we are unable to perceive any object distinctly. Persons who suffer from this imperfection are said to be *short-sighted*, and they are obliged to wear spectacles formed of concave lenses, which, having the property of dispersing light, compensates for its too great refraction by the humors of the eye, and thus causes the focus, or point at which the rays meet, to fall exactly on the retina, where then, of course, a perfect picture is produ-



ced. This will be better understood by the annexed diagram, where the rays are seen to converge, after passing through the crystalline lens, and come to a focus before they reach the retina, at the back of the eye.

209. Some persons have a defect the reverse of the foregoing; in consequence of which, the rays of light are not collected into a focus when they reach the retina. They are not refracted enough in passing through the eye, and, consequently, while objects at a distance are distinctly visible, those near the eye are very indistinct. Old persons are generally subject to this defect of vision; the cornea, or front of the eye, becoming flatter in old age than it is in youth; and, therefore, in order to perceive an object clearly, it must be held at some distance from the organ of vision. Old gentlemen and ladies like books printed in a large type, and with wide spaces between, because then the letters are more clear; and they hold the newspaper the other side of the candle, because, if held closer, the letters are indistinct, from the light not being brought to a point on the retina. The diagram annexed will explain the cause of long-sightedness. The rays of light, proceeding

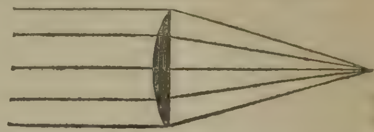
from the cross, it will be seen, *do not come to a focus until they have passed through the retina* at the back of the eye, and, consequently, a perfect image is not formed on it. If a convex glass be held in front of the eye of a person suffering from this imperfection, he will see very clearly; because it is the property of convex lenses to refract light very powerfully, and spectacles of this kind must be used by such persons.

210. It will be perceived, by the above diagrams, that the images of all objects formed on the retina must be in an *inverted* position, and this may be rendered evident by experiment. (See experiment 227.) Yet we are unconscious that this is the case with ourselves; everything appears upright, and in its proper position; but this is because, while we become acquainted with the color of an object by its picture on the retina, we judge of its position by the direction in which the light comes from it to the eye.

211. There is, indeed, no organ of sense so liable to deceive us as the eye; and, unless corrected by the other senses, we should be constantly led into error The axiom, that "Seeing is believing," may frequently be proved false. We see, for instance, a rocket, ascending into the air, and although we know that it is only a small body alight at one end, yet, to our eyes, it appears a long line of flame. This is a deception to which we are liable, in consequence of a peculiarity of the retina, by which any impression made upon it lasts for about *the sixth part of a second.* If, therefore, a succession of similar impressions be made upon it, with great rapidity, one will not have passed away before another is made, and thus the impression will appear continuous. Sir David Brewster has given many remarkable illustrations of this curious property of the retina; some of which will be found amongst the experiments which follow, and other examples are given, which, it is hoped, will be sufficient to explain many of the absurd stories respecting ghosts and apparitions, in which some people so earnestly believe; for it will be evident, that a man may actually see an apparition *with his eyes shut!* The retina has the power of recalling an object that has once been impressed upon it; and, therefore, when the mind is internally engaged in recalling to recollection the person of some dear friend, deceased, it is easy to believe that the retina may have the image of the individual recalled, and thus apparently make him, in reality, appear before us. The sensibility of the retina, with regard to colors, is likewise a cause that has frequently been deceptive. This is fully explained in the pages which follow.

212. Another source of deception may be found in the power which lenses have of changing the direction of light; as in the case of the eye, camera obscura, &c.

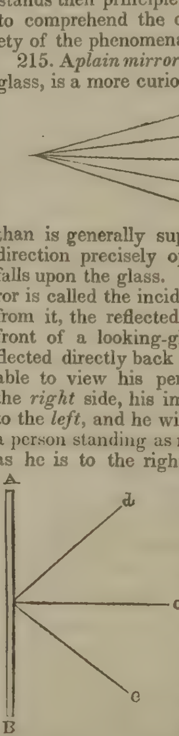
213. A convex lens possesses the property of concentrating the rays of light, and may therefore be accordingly used as a "burning glass." The greater the convexity of the lens, the nearer will be its focus; for the curious fact has been discovered, that the focus of a double lens of glass is just where the centre of the sphere would be, of which the surface of the lens is a portion; and, therefore, the *greater* the convexity of the lens, the *nearer* the focus will be, as the surface, in that case, is a portion of a smaller sphere. We learn from this why the more powerful the microscope is, the nearerthe object to be examined must be brought to it; and many pleasing illustrations may be madewith the convex mirror, that forms an elegantpiece of furniture for the parlor.



214. A *concave lens,* instead of converging the rays of light, disperses them; and, as has just been mentioned in the case of short-sighted persons, may be used to compensate for too great refraction by convex lens. This and the concave lens are the two principal forms; they are modified in various ways, and a person who understands their principle of action, will be able to comprehend the cause of a great variety of the phenomena of nature.

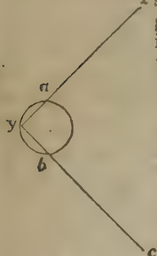
215. A*plain mirror*, or common looking-glass, is a more curious optical instrument

than is generally supposed; it reflects light in a direction precisely opposite to that in which it falls upon the glass. The ray falling on the mirror is called the incidental ray, and that reflected from it, the reflected ray. If a person stand in front of a looking-glass, his image will be reflected directly back to himself, and he will be able to view his person; if he stand a little on the *right* side, his image will be reflected a little to the *left*, and he will no longer see himself; but a person standing as much to the left of the glass as he is to the right of it, will see him, and he will see the person. Suppose A and B a lookingglass, then all the rays of light coming from C are reflected directly back on the object from which they came, and a person standing there will see himself; if he moves to D, the light is reflected to E, and, therefore, only a person standing exactly at E will be able to see him. At the same time, he will be able to see any object at E, because its light will be reflected exactly where he stands at D. A knowledge of this principle enabled the magicians, as they were called in an-



cient times to perform many surprising experiments, by which they imposed upon the people, who were ignorant of the cause, and made them believe that they were gifted with extraordinary powers by the Creator; while, in fact, they were only using his name to beguile and mislead those who believed them.

216. *The rainbow*, that "miracle of beauty," depends on the refractive power of the drops of rain, in the same way as the prismatic colors that we see reflected from a chandelier, depend on the refracting property of glass. A person who understands what has just been said, respecting the different qualities of plain and convex and concave mirrors, will easily comprehend the cause of the rainbow, from the following description:—When the sun shines upon the spherical drops of rain, and, its light falling upon the whole central part of any drop, passes completely through it (as it would if it entered opposite Y in the cut:) still that portion which enters near the edge of the drop, as at *a*, from the sun at *r*, is *refracted*, and reaches the back surface of the drop at *y*, so slantingly, or at an angle so great, that it is entirely *reflected*, instead of being transmitted; the ray, therefore, is returned to *b*, where it again escapes from the drop, and, as here shown, descends to the earth, or the eye, at *c*. Thus, every drop of rain on which the sun shines is a little mirror supended in the sky, and returns, at a certain angle all around it, a portion of the light which falls on it; and an eye placed in the required direction, receives that reflected light, in the same way that an object is perceived by reflection in a mirror, as illustrated by a previous diagram.



It may be asked why, if the rainbow depends on drops of falling rain, does it not immediately disappear as the rain reaches the ground? This is really the case; we do not see the *same* rainbow for two seconds together; for immediately the drop that reflects the light passes the spot on which the eye is fixed, we no longer perceive the rays coming from it, but we have a continued impression of the rainbow, because as fast as one drop passes away, another supplies its place, and we do not perceive any intermission in the colors reaching the eye, because, as previously explained, an impression remains on the retina for the sixth part of a second, and the reflection from each drop comes more quickly than this. The light being *refracted* by the raindrops, is resolved into its elementary colors; and these, with their combinations, appear in the following order, commencing from the internal portion of the bow—viz, red, orange, yellow, green, blue, indigo, and violet. These are called the prismatic colors, and it was formerly supposed that they were the elements of white light; but at the present time it is more generally believed that the elementary colors are but red, yellow, blue, and violet, and that these, by uniting, form the additional tints; thus, red and yellow form orange, and the orange ray is found between the red and yellow rays; and the same principle is applied to explain the appearance of the green and indigo rays. Independent of the religious feelings that naturally associate themselves with the rainbow, there are few natural phenomena more calculated to impress us with a conviction of the benevolence of the Creator. It shows, not merely that our animal wants have been provided for but that provision has been also made for gratifying our taste for the beautiful. What can be more exquisitely lovely than the colors of the rainbow? If light had not been formed of colored rays, we might, it is true, have had a rainbow in which a thousand little images of the sun would have been reflected to us; but they would not have had the effect of the present arrangement: they would all have been of one monotonous color—white. Had this been the case, too, what an unlovely spectacle would nature have presented, compared with her present appearance! The rose might have retained its odor, but how much of its sweetness would it have lost had the color, which now adorns it, been wanting! The form and countenance of man, too, might have been as regular and perfect as it is, but what would have supplied the blooming tint that indicates both youth and health, and which, in the female, sex, bestows a charm that art can never imitate? Indeed, throughout nature, although nearly every phenomena could take place as regularly with light of one color only, as by its consisting of several, yet, had such been the case, how many of those enjoyments and pleasures would have been lost to us, that we now derive from the beautiful colors which so profusely adorn the works of the Creator?

EXPERIMENTS IN LIGHT AND OPTICS.

Velocity of Light—Light travels in straight lines—Light produced from quartz stones—To obtain a light from loaf sugar—Transparency of gold—Refraction of light—A natural camera obscura—How to make a camera obscura—Dark spot on the retina—Insensibility of the optic nerve—Curious effect of indirect vision—Illusion of the eye with respect to the situation of objects—The magic lantern—Duration of impressions on the retina—the circle of fire—The thaumathrope—Composition of light—Long-continued image of the sun on the retina—To read the inscription of a coin in the dark—To read the inscription that has been erased from a coin—Laughable effect of homogeneous light—Heat of the colors of the spectrum—To show that light and heat are distinct in the sun's rays—Prismatic colors—Ocular spectra, or accidental colors—Phosphorescence of the sea illustrated—Phosphorescence of the retina—Solar phosphori—Breathing light and darkness—Changes of the kaleidoscope.

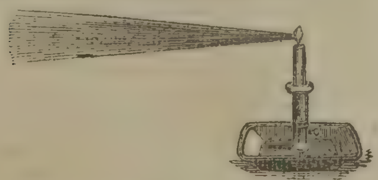
VELOCITY OF LIGHT.

217. Light travels with the amazing velocity of 192,000 miles in a second of time; so that it has been pleasingly remarked, that during a single vibration of a commou clock pendulum, it would go from London to Edinburgh, and back, 200 times, although the distance between these places is 400 miles. It may be interesting to know how philosophers have been able to determine, with such certainty, that light really travels with this amazing velocity; for the fact is known as certainly as any phenomenon in nature. The method adopted was the following:—The eclipses of the satellites or moons of the planet Jupiter had been carefully observed for some time, and a rule was obtained, which foretold the instants, in all future time, when the satellites were to glide into he shadow of the planet, and disappear, or again to emerge into view. Now it was found that

these appearances took place sixteen minutes and a half sooner when Jupiter was near the earth, or on the same side of the sun with the earth, than when it was on the other side; that is to say, more distant from the earth by one diameter of the earth's orbit, or path in the heavens which it takes in revolving round the sun, and at all intermediate stations, the difference diminished from the sixteen minutes and a half, in exact proportion to the less distance from the earth. This proves, then, that light takes sixteen minutes and a half to travel across the earth's orbit, and eight minutes and a quarter for half that distance, or to come to us from the sun. This being its amazing velocity, it may, for all useful purposes on the earth, be regarded as passing between bodies instantaneously; and it is for this reason that we perceive the flash from a gun at a distance, for a perceptible time, before we hear the report, and why we may count several seconds between the appearance of a flash of lightning, and hearing the thunder which follows.

LIGHT TRAVELS IN STRAIGHT LINES.

218. To prove that light proceeds from luminous bodies, in straight lines (see introduction,) procure a straight flexible tube, and look through it at any object, which will then be distinctly visible. If, however, one end of the tube be now bent, either upwards or downwards, on looking into the tube, it will be found perfectly dark; the light coming in at the bent end *will not turn a corner*, and, consequently, none of it reaches the eye. The annexed engraving of a beam of light proceeding from a candle will illustrate the fact of light proceeding in right lines.



LIGHT PRODUCED FROM QUARTZ STONES.

219. If two of these stones (milk stones, as boys sometimes call them) be struck against each other, they will emit light; and if they are struck under water, the same effect will be produced.

TO OBTAIN A LIGHT FROM LOAF SUGAR.

220. If two large pieces of loaf sugar (the larger the better) be struck against each other in the dark, a light blue flame, like lightning, will be produced. The same effect takes place when a grocer chops up a lump of sugar with his iron hatchet, only it is not often noticed.

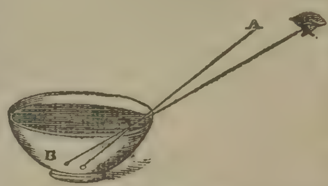
TRANSPARENCY OF GOLD.

221. All opaque substances might become transparent if they could be made sufficiently thin; and what it is in the constitution of one mass, as compared with another, which fits the former to transmit light, and the latter to obstruct it, cannot clearly be explained; but we perceive that the arrangement of the particles has more influence than their peculiar nature. Nothing is more opaque than thick masses of the metals; but nothing is more transparent than equally thick masses of the same metals in solution, nor than the glasses, of which a metal forms a large proportion. The thousand salts formed by the union of the metals, or earths, with the diluted acids, are all transparent when, in cooling from the fluid to the solid state, their particles have been allowed to arrange themselves according to the laws of their mutual attraction—that is to say, to form crystals; but the same substances in other states, as when reduced to powder, are opaque. Even the metals themselves when reduced to leaves of great thinness, are transparent, as may be perceived by looking at a lamp through a fine gold leaf. The light will be visible, but the flame will appear of a greenish hue.

REFRACTION OF LIGHT.

222. A beam of light passing the atmosphere into any denser medium, such as water, or glass, or even into a heavier gas, is bent, or *refracted* (see Introduction, 206;) and light passing from a dense into a lighter medium, suffers an opposite change in its direction. Refraction, however, does not take place if the light falls *perpendicularly* upon a surface; it is only when it falls *obliquely*, that it is bent out of its course. The following experiments will illustrate the refraction or bending of light by water.

223. Place a coin in a vessel, so that on standing at a certain distance off, it is just hid by the edge of the vessel. Then get some one to pour water into it, and the coin will immediately become visible;

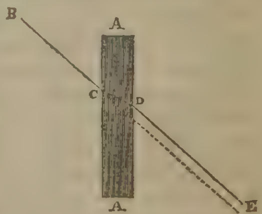


it will appear to have moved from the side to the middle of the vessel as shown by the cut.

224. If a basin, or other vessel, be placed so that a ray of the sun shall fall low on one side within it, on filling it up with water, the image of the sun will appear shinning on the bottom of the vessel; the water having refracted the beam of light which fell on the side so much, that it then falls on the bottom.

225. Place a stick upright in a tub, and afterwards fill it up with water; or place a stick in a vessel of water, and it will appear bent and crooked.

226. A ray of light which passes through a piece of plate glass will suffer considerable refraction, after the manner represented in the annexed engraving, where A is the piece of glass, C and D the parts where the ray enters and emerges, falling on E; and the dotted line shows the degree of refraction,



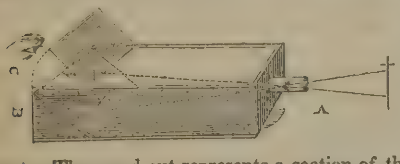
A NATURAL CAMERA OBSCURA.

227. The human eye is a camera obscura; for on the back of it, on the retina, every object in a landscape is beautifully depicted in miniature

(see Introduction.) This may be proved by procuring a bullock's eye, and carefully removing, or thinning, the *outer* coat of it behind, taking care not to cut it, or the vitreous humor will escape, and the eye be rendered useless. If the pupil of it be directed to any bright objects, when it is thus prepared, they will appear beautifully distinct in miniature on the back part, precisely the same as objects appear in the camera obscura. The effect will be hightened if the eye is viewed in a dark room, with a small hole in the shutter; but in every case the appearance will be very striking.

HOW TO MAKE A CAMERA OBSCURA.

228. This is a very pleasing and instructive little piece of apparatus, and may be purchased for three or four shillings. As some of our readers, however, may like to make one themselves, and as this may be done at a very trifling expense, we give the following directions for the purpose: Make an oblong box, about a foot long, six inches wide, and three or four high; at one end make a round hole, in which fix a small magnifying glass, which may be obtained at any optician's. Then, at the other end, place a piece of looking-glass, slantingly, so that when the light falls on it after passing through the magnifying glass, it may be reflected to the top of the box, near the end. On this part place a piece of ground glass, or transparent oiled paper, and, after covering the remainder of the top with wood, and blacking the inside with ink all over, the camera obscura is complete. On pointing the end of the box to a landscape, the light will pass through the lens, and every thing will appear beautifully distinct, in miniature, on the ground glass. If, therefore, a piece of writing paper be placed on it, a very pleasing drawing may be made with a pencil; and thus the camera obscura may be made an endless source of pleasure and instructive amuse-



ment. The wood cut represents a section of the apparatus; A, is the lens; B, the back, against which rests the looking-glass; and C is the ground glass, on which the paper is laid,

DARK SPOT ON THE RETINA—INSENSIBILITY OF THE OPTIC NERVE.

229. There are few persons aware, that when they look with one eye, there is some particular object before them to which they are absolutely blind. If we look with the right eye, this point is always about 15° to the right of the object which we are viewing, or to the right of the axis of the eye, or the point of most distinct vision.—If we look with the left eye, the point is far to the left. In order to be convinced of this curious fact, which was discovered by M. Mariotte, place two colored wafers upon a sheet of white paper, at the distance of three inches apart, and look at the *left*-hand wafer with the *right* eye, at the distance of eleven or twelve inches, the experimenter standing in front of the wafers, taking care to keep the eyes straight above the wafer, and the line which joins the eyes parallel to the line which joins the wafers. When this is done, and the left eye closed, the right-hand wafer will no longer be visible. The same effect will be produced if we close the right eye, and look with the left eye at the right-hand wafer. When we examine the retina, to discover to what part of it this insensibility to light belongs, we find that the image of the invisible wafer has fallen on the base of the optic nerve, or the place where this nerve enters the eye, and expands itself to form the retina, which is a kind of network-expansion of the optic nerve over the interior coat of the eye, and is the part on which impressions are made, that render external objects visible to us (see Introduction.)

230. If the above experiment be performed with candles, instead of wafers, the candle on either side will not entirely disappear, but leaves behind a faint, cloudy light, without, however, giving any thing like an image of the object from which the light proceeds. From a knowledge of the preceding facts we might, perhaps, be led to imagine, that on viewing a landscape, whether we use one or both eyes, to see a black or dark spot within fifteen degrees of the point which most particularly attracts our notice. The Divine Artificer, however, has not left his work thus imperfect. Though the base of the optic nerve is insensible to light that falls directly upon it, yet it has been made susceptible of receiving luminous impressions from the parts which surround it; and the consequence of this is, that when the wafer disappears, the spot which it occupied, in place of being black, has always the same color as the ground upon which the wafer is laid—being white when the wafer is placed upon a white ground, and red when it is placed upon a red ground. This curious effect may be rudely illustrated, by comparing the retina to a sheet of blotting-paper, and the base of the optic nerve to a circular portion of it, covered with a piece of sponge. If a shower falls upon the paper, the protected part will not be wetted by the rain which falls upon the sponge that covers it; but in a few seconds it will be as effectually wetted by the moisture which it absorbs from the wet paper with which it is surrounded. In like manner, the insensible spot on the retina is stimulated by a borrowed light; and the apparent defect is so completely removed, that its existence can be determined only by the experiment already described.

CURIOUS EFFECT OF INDIRECT VISION.

231. When the eye is steadily occupied in viewing any particular object, or when it takes a fixed direction, while the mind is intently engaged on any subject of contemplation, it suddenly loses sight of, or becomes blind to, objects seen indirectly, or upon which it is not fully directed. In order to witness this illusion, put a little bit of white paper on a green cloth, and within three or four inches of it place a narrow strip of white paper. At the distance of twelve or eighteen inches, fix one eye steadily upon the little bit of white paper, and in a short time a part, or even the whole of the strip of paper will

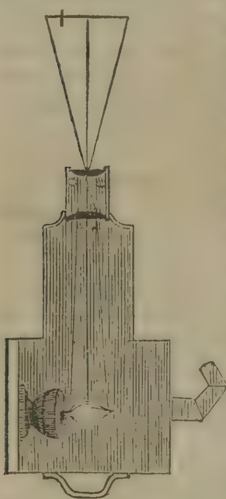
vanish, as if it had been removed from the green cloth. It will again appear, and again vanish; the effect depending greatly upon the steadiness with which the eye is kept fixed. This illusion takes place when both the eyes are open, though it is easier to observe it when one of them is closed. The same thing happens when the object is luminous, instead of being a bit of paper. When a candle is thus seen by indirect vision, it never wholly disappears, but it spreads itself out into a cloudy mass; the centre of which is blue, encircled with a bright ring of yellow light.

ILLUSION OF THE EYE WITH RESPECT TO THE SITUATION OF OBJECTS.

232. Take a ring, of about an inch in diameter, and suspend it from a piece of string, so that it may hang on a level with the middle of the face, and with the edge toward the eyes, so that the orifice of the ring cannot be seen. If one eye be then closed, it will be found nearly impossible to thrust the end of a stick through the ring, as the eye will be deceived with regard to the situation of the ring; although this may be accomplished easily when both eyes are open.

THE MAGIC LANTERN.

233. This well-known and pleasing philosophical toy is so great a favorite, that it requires no recommendation to introduce it to the notice of the student in optics. Its principle will be best understood from the annexed engraving, showing the form of the instrument, and the situation of the lenses employed. These lenses are set in a tube, which can be lengthened or shortened at pleasure, in order to adjust the image of the object on the wall, or other surface on which it is projected. Probably, by the assistance of the wood cut, some of our readers may be enabled to construct a magic lantern; and the pleasure tobe derived from it will amply recompense for a little trouble. To use it, it is advisable to hang up a table-cloth, or sheet, on a line at a little distance from the wall of a room, and for the exhibitor to stand behind it, as by this means he can increase or diminish the size of the objects at pleasure, by adjusting the tube, and standing near, or at a distance from the cloth. Grotesque figures, animals, &c, painted on glass slides, having the other parts covered with black varnish, to prevent the transmission of light, except through the figure, are generally used to exhibit the powers of the magic lantern, and may be made with a little ingenuity, or purchased at the optician's, where the lenses may also be obtained. Their situation will be seen from the cut.

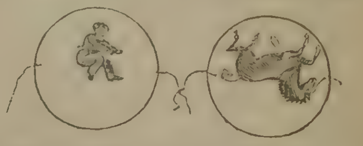


DURATION OF IMPRESSIONS ON THE RETINA—THE CIRCLE OF FIRE.

234. It was formerly thought that these impressions disappeared from the retina the moment the object that produced them was removed from before the eye; but this is found not to be the case, for an impression—that is to say, a picture in miniature of any thing held before our eyes—remains on the retina about the sixth part of a second after the body that produced it has been withdrawn (see Introduction). This may appear so very inconsiderable a portion of time, as hardly to be of much importance; but it enables us to explain the cause of many striking phenomena connected with vision, that would otherwise be inexplicable. The following pleasing experiments may be performed, to show the effect of the retina retaining an image of an object after it is withdrawn from before the eye:—Take a short piece of wood, and, having burnt one end of it, so that it shall remain luminous, tie it to a piece of string, and swing it rapidly round in a circle. The effect will be, that we shall perceive a complete circle of fire. If a piece of ignited charcoal be fixed to the rim of a wheel, to which a rapid motion is then given, the same effect will be produced, The cause of this appearance will be understood from the preceding observations. The eye is fixed on a particular part of the wheel where the charcoal is placed, and the image of the burning charcoal will remain on the retina *the sixth part of a second:* it is evident, therefore, that if we can turn the wheel so rapidly that the charcoal shall revolve and reach the spot on which our eye is fixed in less time than this, that we shall not be informed, by *our eyes,* of its having moved at all; for an image of the burning charcoal will be constantly on the retina. As it does not matter on what part of the wheel we place our eyes to perceive the same effect, the consequence is, that the whole of the rim of the wheel appears on fire.

THE THAUMATHROPE.

235. Dr. Paris designed a very pleasing toy to illustrate the property of the retina; described in the last experiment; it is called "the thaumathrope, and may be easily constructed in a variety of forms, by the exercise of a little ingenuity.—The toy may be purchased, but we advise the reader to make it himself; which may readily be done from the following directions:—Cut a piece of card round, about the size of half a crown, and fix a piece of thread on opposite sides of the circumference; then paint on one side of the card some little object, such as a man without a



hat, and on the other side, near the top, a hat by itself, reversed. Now, on twisting the card quickly round, by means of the threads, the hat will appear *on the man's head;* for the impression of one side of the card on the retina will not have ceased before the other side is presented to

the eye. A variety of objects may be painted on the card; such as a man and a horse (as in the above cut), a juggler and a number of balls, two men with drawn swords, &c. Indeed, there are a few philosophical toys that afford better opportunities for the display of taste and ingenuity than the thaumathrope.

COMPOSITION OF LIGHT.

236. A beam of light, passing through a prism, is decomposed; and if the rays be received on a sheet of white paper, they will appear of the same number and colors as they do in the rainbow; viz. red, orange, yellow, green, blue, indigo, and violet. It is supposed by philosophers, in the present day, that the orange, green, and indigo colors are not elementary, like the others, but are formed by the *mixture* of the rays from the red and yellow, yellow and blue, and blue and violet parts of the spectrum. Sir Isaac Newton first proved that white light was not one color, as had previously been supposed; and its composition may be pleasingly illustrated in the following manner:—Paste a sheet of white paper on a circular piece of board, about six inches in diameter, and divide it, with a pencil, into fifty parts (see cut). Then paint a portion, equal to six parts, of a red color; four parts, orange; seven, yellow; eight, green; eight, blue; six, indigo; and eleven, violet. The colors should be of a dark tint in the centre, and gradually become

fainter at the edges, till they mix with the one adjoining. If the board be then fixed on an axle, and made to revolve quickly, the colors will no longer appear separate and distinct, but becoming gradually less visible, they will ultimately appear *white*, giving this appearance to the whole surface of the paper.

LONG-CONTINUED IMAGE OF THE SUN ON THE RETINA.

237. The experiments just mentioned will be sufficient to illustrate a few of the curious effects that are produced, in consequence of objects remaining on the retina after they have been removed from before the eye; but, occasionally, effects of a very alarming character have been produced from the same cause; and as it is certain that nearly all ghosts and apparitions, which persons have asserted they have seen, existed in their eyes, in consequence of circumstances connected with this particular property of the eye, the following account of an experiment, performed by Sir Isaac Newton, may be both entertaining and useful. Any of our readers may perform a similar experiment by looking, for some time, steadily, at a burning body, such as a candle, for example; but, probably, after reading the following anecdote, they will be content without personally performing the experiment.

238. Mr. Boyle having mentioned, in his "Book on Colors," an individual who continued, for years, to see the sun whenever he looked upon bright objects, in consequence of having once steadily contemplated that luminary for a considerable period, Locke mentioned the case to Newton, who gave the following account of a similar occurrence that had happened to himself:—"The observation you mention in Mr. Boyle's 'Book of Colors,' I once made upon myself, with the hazard of my eyes. The manner was this: I looked, a very little while, upon the sun in the looking-glass, with my right eye, and then turned my eyes into a dark corner of my chamber, and winked to observe the impression made, and the circles of colors which encompassed it, and how they decayed by degrees, and at last vanished. This I repeated a second and a third time. At the third time, when the phantasm of light, and colors about it, were almost vanished, intending my fancy upon them to see their last appearance, I found, to my amazement, that they began to return; and, by little and little, to become as lively and vivid as when I had newly looked upon the sun. But when I ceased to intend my fancy upon them, they again vanished. After this, I found that as often as I went into the dark, and *intended* my mind upon them, as when a man looks earnestly to see any thing that is difficult to be seen, I could make the phantasm return, without looking any more upon the sun; and the oftener I made it return, the more easily I could make it return again: and at length, by repeating this, without looking any more upon the sun, I made such an impression on my eye, that if I looked upon the clouds, or a book, or any bright object, I saw upon it a round, bright spot of light, like the sun; and, which is still stranger, though I looked upon the sun with my right eye only, and not my left, yet my fancy began to make an impression on my left eye, as well as upon my right: for if I shut my right eye, and looked upon the clouds, or a book, with my left eye, I could see the spectrum of the sun almost as plain as with my right eye, if I did but intend my fancy a little time upon it; for at first, if I shut my right eye, and looked with my left, the spectrum of the sun did not appear till I intended my fancy upon it; and, by repeating this, appeared every time more easily. And now, in a few hours time, I had brought my eyes to such a pass, that I could look upon no bright object with either eye, but I saw the sun before me, so that I durst neither write nor read; but to recover the use of my eyes, shut myself up in my chamber, made dark, for three days together, and used all means in my power to direct my imagination from the sun; for if I thought upon him, I presently saw his picture, though I was in the dark. But, by keeping in the dark, and employing my mind about other things, I began, in three or four days, to have more use of my eyes again; and by forbearing to look upon bright objects, recovered them pretty well—but not so well but that, for some months after, the spectrums of the sun began to return as often as I began to meditate

upon the phenomenon, even though I lay in bed at midnight, with my curtains drawn. But now I have been well for many years; though I am apt to think, if I durst venture my eyes, I could still make the phantasm return, by the power of my fancy." This experiment proved how easily the image of a bright object might be recalled, and the mind be deceived by an appearance that was not real. There can be no doubt but that persons have often, in this manner, had the forms of deceased friends recalled so vividly, that they have appeared to be actually present; and persons not acquainted with the fact that the eye can deceive the mind in this way, would never doubt the reality of what they thought they saw.

TO READ THE INSCRIPTION OF A COIN IN THE DARK.

239. To do this, take a silver coin, and after polishing the surface as much as possible, make the parts of it which are raised rough, by placing on them a little oil of vitriol, or some other acid; the parts not raised are to be left polished. If the coin thus prepared is placed upon a mass of red-hot iron, and removed into a dark room, the inscription upon it will become distinctly visible, and may be read by a spectator. The mass of red-hot iron should be concealed from the observer's eye, by having something placed before it, both for the purpose of rendering the eye fitter for observing the effect, and of removing all doubt that the inscription is really read in the dark; that is, without receiving any light, direct or reflected, from any other body. If, instead of roughening the raised parts of the coin by an acid, we polish the raised parts and roughen the depressed parts, we shall still be able to read it, from its being, as it were, written in black letters upon a white ground—the reverse of the first experiment.

TO READ THE INSCRIPTION THAT HAS BEEN ERASED FROM A COIN.

240. When such a coin is laid upon the red-hot iron, the letters and figures that have been either wholly obliterated, or obliterated to such a degree as to be illegible, become oxidated, or rusted; and the film of oxide radiating more powerfully than the rest of the coin, the illegible inscription may be now distinctly read, to the great surprise of an observer who had previously examined the blank surface of the coin.

241. In order to explain the cause of this remarkable phenomenon, and that of the previous experiment, it is necessary to notice a method, that has been long known, of deciphering the inscriptions on worn-out coins. This is done by merely placing the coin upon a hot iron; an oxidation takes place over the whole surface of the coin, the film of oxide changing its tint with the intensity or continuance of the heat. The parts, however, where the letters of the inscription had existed, oxidate at a different rate from the surrounding parts; so that these letters exhibit their shape, and become legible, in consequence of the film of oxide which covers them having a different thickness, and therefore reflecting a different tint from that of the surrounding parts. The tints thus developed sometimes pass through many orders of brilliant colors—particularly *pink* and *green*, and settle in a bronze, and sometimes a black tint, resting upon the inscription alone. When the experiment is often repeated, the coin loses its property of becoming luminous in this way; but regains it on being exposed for a time to the atmosphere. The reason that the parts of a coin, that has been roughed by an acid, become more luminous than the parts that are left in a polished state, is, because all black and rough surfaces radiate light more copiously than polished and smooth surfaces; and hence the inscription is luminous when it is rough, and obscure when it is polished.

LAUGHABLE EFFECT OF HOMOGENEOUS LIGHT.

242. An experiment, productive of much amusement, and at the same time well illustrating the cause of colors, may be performed with homogeneous light. If a little spirits of wine—or some spirit, such as gin—be ignited in a dish, and a quantity of common table salt thrown on it, the lights in the room having been previously put out, every person present will have a most ghastly look, and their clothes will assume an extraordinary color; the hue of health will disappear from the cheeks, and the different articles of clothing will entirely change their complexion.—The cause of this phenomenon will be found in the circumstance, that the color of bodies depends upon the rays of light being partly absorbed, and partly reflected. A ray of white light can be shown to consist of seven prismatic colors, as they are called (see experiment 246), and different bodies possess the power of absorbing one or more of these colors, and reflecting all the rest; and the combination of the rays that are reflected gives the particular color to an object. Red-colored bodies, for instance, absorb all the rays, *except the red* ray; and this accordingly appears to be the color of the body—and so on of all other colors. When, therefore, homogeneous light is produced by the means above mentioned, as the articles of dress, and the faces of the company, do not absorb all the yellow rays, but reflect a portion, the color of every thing is changed.

243. If we were to illuminate scarlet cloth with pure and unmixed yellow light, it would appear yellow, because the scarlet cloth does not absorb all the yellow rays, but reflect some of them; and if we illuminate *blue* cloth with *yellow light*, it will appear nearly *black*, because it absorbs all the yellow light, and reflects hardly any of it. But, whatever be the nature and color of the bodies on which the yellow light falls, they must appear yellow; for no other light falls upon them, and those which are not capable of reflecting yellow light must appear absolutely black, however brilliant be their color in the light of day. This is the cause of the curious appearance of the company when homogeneous light is produced, as above mentioned.

HEAT OF THE COLORS OF THE SPECTRUM.

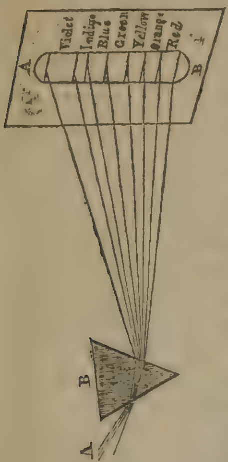
244. The heating powers of the rays of the solar spectrum are found to be of different degrees. If the bulb of an air thermometer be moved in succession through the differently-colored rays, it will be found to indicate the greatest heat in the red rays; next in the green; and so on, in a diminishing progression, to the violet.

TO SHOW THAT LIGHT AND HEAT ARE DISTINCT IN THE SUN'S RAYS.

245. If the thermometer be removed entirely

out of the confines of the red rays, but with the bulb still in the line of the spectrum, it rises even higher than in the red rays, and continues to rise till removed half an inch beyond the extremity of the red ray. In this situation, quite out of the visible light, the thermometer has been known to rise, in two minutes and a half, from 61 degrees to 70 degrees. The ball of the thermometer employed should be extremely small, and be blackened over with India Ink.

PRISMATIC COLORS.



246. Cut a small slit in a window-shutter(A,) on which the sun shines at some period of the day; and directly opposite the hole, place a prism (P). A beam of light, in passing through it, will be decomposed; and if the light fall on a sheet of paper, or against a white wall, the seven colors of the rainbow will be observed, as in the engraving (see Introduction.)

247. If the split in the window-shutter be very small, and no prism is placed opposite to it, only four colors will appear—viz. red, green, yellow, and violet.

OCULAR SPECTRA, OR ACCIDENTAL COLORS.

248. If we cut a figure out of red paper, and, placing it on a sheet of white paper, view it steadily for some seconds, with one or both eyes fixed on a particular part of it, we shall observe the red color to become less brilliant. If we then turn the eye from the red figure upon the white paper, we shall see a distinct *green* figure, which is the *spectrum*, or accidental color of the *red* figure. With differently-colored figures, we shall observe differently-colored spectra, as in the following table:—

Color of the original figure.	*Color of the spectral figure.*
Red	Blueish Green.
Orange	Blue.
Yellow	Indigo.
Green	Reddish Violet.
Blue	Orange Red.
Indigo	Orange Yellow.
Violet	Yellow.
White	Black.
Black	White.

249. The two last of these experiments, viz., white and black figures, may be satisfactorily made by using a white medallion on a dark ground, and a black profile figure. The spectrum of the former will be found to be black, and that of the latter white.

250. These ocular spectra often show themselves without any effort on our part, and even without our knowledge. In a highly-painted room, illuminated by the sun, those parts of the furniture on which the sun does not directly fall, have always the opposite, or accidental color. If the sun shines through the chintz in a *red* window-curtain, its light will appear *green*, varying, as in the foregoing table, with the color of the curtain; and if we look at the image of a candle, reflected from the water in a blue finger *glass*, it will appear *yellow*. Whenever, in short, the eye is affected with one prevailing color, it sees, at the same time, the spectral or accidental color, just as when a musical string is vibrating, the ear hears, at the same time, its fundamental and its harmonic sounds.

PHOSPHORESCENCE OF THE SEA ILLUSTRATED.

251. The sea frequently presents a very beautiful phosphorescent appearance, which arises, in most cases, from the presence of innumerable quantities of exceedingly minute living creatures, like glow-worms, furnished with the means of becoming phosphorescent. The effect they produce may be imitated with a basin of water, in the following manner:—Pour a little phosphoretted ether on a lump of sugar, and drop it into the water, which should be made lukewarm. In a dark place, the surface of the water will soon become luminous; and if it be moved, by blowing gently with the mouth, beautiful and brilliant undulations of the surface will be visible, exhibiting the appearance of liquid combustion. Those who cannot see the ocean in a flame, may adopt this method of feebly imitating it; and it will serve to give them a faint idea of a phenomenon, which has called forth the admiration of all who have ever seen it.

PHOSPHORESCENCE OF THE RETINA.

252. A class of ocular deceptions have their origin in a property of the eye, and they have been very imperfectly examined. The fine nervous fabric which constitutes the retina, and which extends to the brain, has the singular property of being phosphorescent by pressure. When we press the eye-ball outward, by applying the point of the finger between it and the nose, a circle of light will be seen, which Sir Isaac Newton describes as "a circle of colors, like those in the feather of a peacock's tail." He adds, that "if the eye and the finger remain quiet, these colors vanish in a second of time; but if the finger be moved, with a quavering motion, they appear again." The luminous circles always continue while the pressure is applied, and they may be produced as readily after the eye has been long in darkness, as when it has been recently exposed to light. When the pressure is very gently applied, so as to compress the fine pulpy substance of the retina, light is immediately created, when the eye is in total darkness; and when in this state, light is allowed to fall upon it: the part compressed is more sensible to light than any other part, and, consequently, appears more luminous. If we increase the pressure, the eye-ball, being filled with incomprehensible fluids, will protrude all round the point of pressure; and, consequently, the retina, at the protracted part, will be *compressed* by the outwurd pressure of the contained fluid, while the retina on each side—namely, under the point of pressure, and beyond the protruded part—will be drawn toward the protruded part, or *dilated*. Hence, the part under the finger, which was originally compressed, is now *dilated;* the adjacent parts compressed, and the

more remote parts immediately without this, dilated also.

253. Now we have observed, that when the eye is, under these circumstances, exposed to light, there is a bright, luminous circle shading off, externally and internally, into total darkness. We are led, therefore, to the important conclusions, that when the retina is compressed in total darkness, it gives out light; that when it is compressed while exposed to light, its sensibility to light is increased; and that when it is dilated, under exposure to light, *it becomes absolutely blind*, or insensible, to all luminous impressions!

254. When the body is in a state of perfect health, this phosphorescence of the eye shows itself on many occasions. When the eye-ball, or the eye, receives a sudden blow, a bright flash of light shoots from the eye-ball. In the act of sneezing, gleams of light are emitted from each eye, both during the inhalation of the air, and during its subsequent expulsion; and in blowing air violently through the nostrils, two patches of light appear above the axis of the eye, and in front of it, while other two luminous spots unite into one, and appear, as it were, about the point of the nose when the eyes are directed to it.—When we turn the eye-ball, by the action of its own muscles, the retina is affected at the place where the muscles are inserted; and there may be seen, opposite each eye, and toward the nose, two semicircles of light, and other two, extremely faint, toward the temples. At particular times, when the retina is more phosphorescent than at others, these semicircles are expanded into complete circles of light. In a state of indisposition, the phosphorescence of the retina appears in a new and alarming form (see Introduction). When we consider the variety of distinct forms which, in a state of perfect health, the imagination can conjure up when looking into a burning fire, it is easy to conceive how the masses of colored light, which often float before the eyes in illness, may be moulded, by the same power, into those fantastic shapes that often haunt the sick man's couch. Sir D. Brewster has ably illustrated these phenomena in his "Natural Magic."

SOLAR PHOSPHORI.

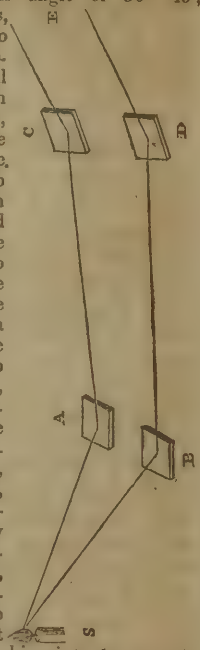
255. There are many substances in nature, which, when heated to a certain degree, acquire the property of becoming luminous at low degrees of temperature, and when merely exposed for a time to the sun. Canton's phosphorus, which is obtained from calcined oyster-shells, possesses this property; and common oyster-shells may be rendered phosphorescent, by attending strictly to the following directions, which are given by the discoverer for the purpose:—Take the most flaming coals off a brisk fire, and throw in some thick oyster-shells; then replace the coals and calcine the shells for an hour. Remove them carefully, and, when cold, it will be found that, after exposing them for a few minutes to the sun, they will glow, when taken into a dark room, with most of the prismatic colors.

256. Fluor spar, several varieties of phosphate of lime, and marble, become luminous, when heated to a certain point, without undergoing combustion. Their luminous property may be best exhibited, by scattering them, in coarse powder, upon an iron plate, heated to redness.

257. Many animal substances are naturally phosphorescent. This property in the glow-worm is well known; and it appears that salt-water fish become luminous in about twelve hours after death, the brilliancy increasing till putrefaction is evident, when it decreases. This effect, however, does not take place in fresh water.

BREATHING LIGHT AND DARKNESS.

258. The following experiment, if performed with care, is exceedingly striking, and beautifully exhibits one of the many optical delusions to which we are liable. Let S be a candle, whose light falls at an angle of 56° 45′, upon two glass plates, (A B), placed close to each other, and let the reflected rays (A C B D) fall at the same angle upon two similar plates (C D), but so placed, that the plane of reflection from the latter is at right angles to the plane of reflection from the former. An eye placed at E, and looking, at the same time, into the two plates, C and D, will see very faint images of the candle (S), which, by a slight adjustment of the plates, may be made to disappear almost wholly, allowing the plate C to remain as it is; change the position of D, till its inclination to the ray B D, D is diminished about 3½°, or made nearly 53° 11′.—This distance may easily be found by a little practice. When this is done, the image that had disappeared on looking into D will be restored; so that



the spectator at E, upon looking into the two mirrors, C D, will see no light in C, because the candle has nearly disappeared; while the candle is distinctly seen in D. If, while the spectator is looking into two mirrors, either he, or another person, breathes upon them gently, and quickly, the breath will revive the extinguished image in C, and will extinguish the visible image in D.—The following is the cause of this singular result:—The light A C B D is polarized by reflection from the plates A B, because it is incident at the polarizing angle, 56° 45′, for glass. When we breathe upon the plates C D, we form upon their surface a thin film of water, whose polarizing angle is 53° 11′; so that if the polarized rays, A C B D, fell upon the plates C D, at an angle of 53° 11′, the candle from which they proceeded would not be visible, or they would not suffer reflection from the plates C D. At all other angles, the light would be reflected, and the candle visible. Now the plate D is placed at an angle of 53° 11′, and C at an angle of 56° 45′, so that when a film of water is breathed upon them, the light will be

reflected from the latter, and none from the former; that is, the act of breathing upon the glass plates will restore the invisible, and extinguish the visable image. This is an experiment of Brewster's.

CHANGES OF THE KALEIDOSCOPE.

259. The following curious calculation has been made of the number of changes this wonderful instrument will admit:—Supposing the instrument to contain 20 small pieces of glass, &c, and that you make 10 changes in each minute, it will then take the inconceivable space of 462,-880,899,576 years, and 360 days, to go through the immense variety of changes it is capable of producing; amounting (according to our frail idea of the nature of things) to an eternity. Or, if we take only 12 small pieces of glass, and make 10 changes in each minute, it will then take 33,264 days, or 91 years and 49 days, to exhaust its variations.

HEAT OR CALORIC.

Introduction to the science of heat—Theories of heat—General effects of heat in nature—Heat the antagonist to attraction—Latent heat—Sources of heat—Combustion—Heat of the sun—Heat produced by friction—Heat by percussion—Heatby chemical mixture—Heatby electricity and Galvanism—Heat by animals—Spontaneous combustion—Properties of heat—Expansion of bodies—Heat—Tendency of Hea to equilibrium—Summary of the properties of heat.

260. HEAT, or caloric, as it is philosophically termed, is the most active principle in nature; there is not a chemical change that takes place, in which it is not concerned, and, without it, vitality would become extinct. We are all familiar with the sensation it causes, and philosophers have been able to determine with exactness, the various phenomena it is capable of producing; but this is all that has been done, for we are as ignorant, in the present day, of what heat really is, as the first philosopher who turned his attention to the subject. The reason of this is, that heat has never been exhibited by itself, apart from material bodies; it is always found in combination with them, and we can, therefore, only judge of its effects. Many theories have, however, been proposed, from time to time, to explain the principle of heat; but, for the reason above stated, they have been necessarily unsupported by facts, and were merely suggestions of the authors.

By some, heat has been thought to be particles of matter that are shut off from burning bodies with amazing velocity; but which, being infinitely small, are incapable of injuring our most delicate organs. Others, again, suppose that it is no material substance, but only the effect produced by certain vibrations among the particles of which all bodies are composed. Both these theories are, however, incapable of proof; and as all the phenomena of heat can be perfectly understood, without any thing of itself as a principle, the student need pay little regard to either of the theories just mentioned, or puzzle himself in endeavoring to understand its essence.

261. Dr. Arnott beautifully describes the general effects of heat in his treatise on that subject. "In the winter of climates," says he, "where the temperature is, for a time, below the freezing point of water, the earth, with its waters, is bound up in snow and ice; the trees and shrubs are leafless, appearing every where like withered skeletons; countless multitudes of living creatures, owing either to the bitter cold, or deficiency of food, are perishing in the snows—nature seems dying, or dead: but what a change when spring or heat returns! The earth is again uncovered and soft; the rivers flow; the lakes are again liquid mirrors; the warm showers come to foster vegetation, which soon covers the ground with beauty and plenty. Man, lately inactive, is recalled to many duties: his water-wheels are every where at work; his boats are again on the canals and streams; his busy fleets of industry are along the shores. Winged life, in new multitudes, fills the sky; finny life similarly fills the waters; and every spot of earth teems with vitality and joy. Many persons regard these changes of season as if they came like the successive positions of a turning-wheel, of which one necessarily brings the next; not adverting that it is the single circumstance of change of temperature which does all. But if the cold of winter arrive too early, they unfailingly produce the wintry scene; and if warmth come before its time in spring, it expands the bud and the blossom, which a return of frost will surely destroy. A seed sown in an ice-house never awakens to life."

262. Heat is the great antagonistic force in nature opposed to *attraction.* While the effect of the latter is to draw the particles of matter in closer contact with each other, the effect of heat is to make them separate; and hence, on the power of heat depends the different states in which bodies are found, either as solids, liquids, or gases. It is well known that, if we apply heat to a lump of ice, it melts and becomes water; and if we continue the heat, this water becomes a gas, called steam. In this instance, therefore, heat is capable of producing all the different states in which matter is found existing in nature; and the experiment proves that it is heat which causes matter to assume these forms.—Water, in its natural state, is liquid; yet the abstraction of the heat peculiar to it, as water, at once reduces it to the solid form; and, in some parts of the world, this is the only state in which it is found. Within the tropics, on the contrary, ice, and its different modifications, snow, hail, &c, are never seen; so that a person, wishing to send a friend within this latitude the greatest curiosity he could from England, packed up a box of snow! He was unable, however, to make the box as impervious to heat as an ice-house; and the only curiosity the friend found, therefore, on opening the box, was a cupful of water! When natives of India, and similar hot countries, arrive in England, nothing occasions them greater surprise than to see water in a solid state; and it is said that an eastern monarch, having called a traveller before him to relate what he had seen in foreign countries, forgave him all the falsehoods he thought he had uttered, until the traveler told him that, in some places, water becomes naturally hard, and could be cut like blocks of marble for several months of the year; upon which, the monarch ordered him instantly to be put to death, for endeavoring to deceive him by the re-

lation of what it was impossible could ever happen.

263. The sensation we experience on approaching a burning body, at once informs us of the existence of heat; but it exists also in all bodies, in a state in which it is insensible to the touch, and in which condition it has no effect upon the thermometer. In this state, it is called *latent* heat. In the following pages, numerous instances are given of its existence in this form, which will enable the reader easily to understand the difference between this and sensible heat; but, in order to explain it briefly here, we may allude again to the changes that take place in water, as illustrations. If an uncovered vessel, containing water, be placed upon the fire, the heat will soon make it boil; and if a thermometer be then placed in it, it will indicate 212 degrees. Now, if the heat be ever so much increased, while the vessel remains uncovered, the water will never become hotter than this; but it will soon evaporate in the form of steam, and all the additional heat applied, after the water has reached a temperature of 212 degrees, is absorbed, to form steam; or, in other words, becomes the *latent heat* of steam. We might suppose that the steam would be hotter than the water, as it receives all this additional heat; but if the thermometer be held in the steam it will not rise higher than 212 degrees: this is because all the heat absorbed by the steam has become *latent;* and if we cool steam, so that it shall return to its original state, as water, it will give out the exact quantity of heat that it required in order to assume the form of steam. The more solid a body becomes, the more latent heat it gives out; so water, when it changes to ice, allows its latent heat to escape: and before ice can again become water, it must absorb a similar quantity to that previously evolved. The temperature of ice is 32 degrees, and water will not freeze until it is cooled to that point; it will not freeze at 33 degrees. We might, therefore, suppose that, by adding *one* degree of heat to ice, we could change it into water; but, in fact, it requires *one hundred and forty degrees*, as one hundred and thirty-nine degrees become *latent*, and we cannot ascertain its presence by the thermometer, or by the touch.

Latent heat exists in all bodies, however cold they may feel; and whenever they are compressed, a portion of this heat will be squeezed out, in the same way that we may squeeze out water from a sponge, although, to the sight, it may appear nearly dry. It will be found, therefore, in the following experiments, that whenever a body is subjected to pressure, heat is forced out; and this will be found the case, not merely with solid bodies, but with liquids, and even with the air itself. (See experiment 284.) The principal sources of heat are, combustion, the sun, friction, percussion, chemical mixture, and Galvanism.—Animals, also, have the power of generating heat during respiration; and there are other means by which it is occasionally produced, such as compression, and what is termed spontaneous combustion; by which animal bodies are consumed without any apparent cause.

264. *Combustion* is the artificial means more generally adopted to produce heat. Certain bodies in nature—such as wood and coals—are called combustibles, and when ignited in any gas which supports combustion—such as the atmosphere or oxygen—chemically combine with this supporter of combustion, and give out much heat that had previously been latent. Sometimes the combustion is instantaneous; sometimes it is slow: this depends on the affinity of the burning body for oxygen; and in the following experiments, many instances are given of the intense chemical action that sometimes takes place.—The laws which regulate combustion are also fully explained, so that it is unnecessary to refer to them here. (See experiment 311.)

265. *The sun* is the principal source of heat, and it is calculated that heat comes to us from that luminary at the amazing velocity of 200,000 miles in a second of time—a speed which it is impossible for us rightly to comprehend. The heat of the sun does not depend on the distance it is from us; for, although we are many millions of miles *nearer* to it in winter than we are in summer, yet winter is coldest; because the rays from the sun fall more obliquely on this part of the globe, at that season of the year, than they do in summer. When the rays fall directly on the earth, there is great heat evolved; and this is principally the reason why the climate is always so hot at the Equator. The heat derived from the sun differs, in many respects, from that procured by other means. It passes readily through glass, while the heat from a fire does not. Some writers have even stated, that artificial heat will not pass through glass at all; but this is a mistake, which any one may ascertain by holding his hand near a gas-glass, while the gas is burning: the heat, however, does not pass through readily, and advantage has been taken of this circumstance in the manufacture of elegant fire-screens, by which persons may enjoy "the Englishman's comfort" of looking at the fire, without experiencing any unpleasant degree of heat. The sun's rays have been found, by experiment, to be divisible into two portions, the one conveying light, the other heat: and it has been ascertained these rays are distinct from each other (see 245); hence it happens, that the light of the sun may be reflected from a body, while its heat is absorbed. This is really the case with the moon. The rays of light proceeding from that luminary are *cold*, and not the slightest degree of heat can be derived from them, even when a number are made to fall on one spot, by means of a "burning-glass." A very different effect is produced when the sun's rays are condensed in a similar manner: the most intense heat may be produced by this means; and, by arranging a number of plain mirrors (looking-glasses) in such a way that the image of the sun from all of them shall fall on one spot, a sufficient degree of heat may be produced, even to melt the metals, gold and platinum. It was by such an arrangement of mirrors, that Archimedes was enabled to set on fire the shipping of the enemy who besieged Syracuse.

266. *Friction* is another means of procuring heat. When two substances are rubbed together, they become warmer; and in machinery, great care is obliged to be taken, in order to prevent any part catching fire from this cause. If a piece of glass, which is incombustible, be held

against the edge of a grit-stone, while revolving, the glass will become too hot to hold: this is in consequence of the friction between the glass and the stone forcing out a portion of their latent heat; for it is only in this way we can account for the heat that is produced. In the experiments which follow, many instances are given, which will more fully explain this phenomena. (See experiment 283.)

267. *Percussion* is the method adopted by house-wives, with a tinder-box, to procure light; and its effects are, therefore, pretty well known. When two bodies are struck together, heat is given out; and if, as is the case of a flint and steel, one of the substances happens to be harder than the other, a portion of the softer substance will often be melted. In the instance alluded to, the flint, being harder than the steel, melts a portion of it, which, while red-hot, falls upon the tinder, and ignites it; thereby producing sufficient heat to melt and light the sulphur on the end of a match. The cause of the heat is supposed to be the sudden compression which the bodies undergo, and which forces out a portion of the heat that had previously been latent. One striking instance of the effect of percussion is given in experiment 285.

268. *Chemical mixture* is a constant source of heat, since all experiments in chemistry, in which the bulk of a body is reduced, produce it; and in other cases, when the affinity of two bodies for each other is suddenly developed by chemical mixture, intense and instantaneous heat is produced. In some cases, however, intense cold is produced by mixture: this is in consequence of the bodies expanding, when, of course, an effect precisely opposite is produced to that which takes place when a body is condensed. Chemical experiments, explaining these facts, are generally very striking and beautiful; and numerous examples will be found in the following pages: it is necessary, however, to caution the student to attend particularly to the directions that are given, and to experiment with very small quantities of the chemicals to be used, by which means, very often, the process will be far more satisfactory, and illustrate the fact much better, than if a large quantity were employed.

269. *Galvanism and Electricity* are the last means that have been alluded to, when describing the principal sources of heat; and for procuring an intense degree of artificial heat, Galvanism is the best method that can be adopted. By its means, all the metals may be fused with the greatest facility; thereby showing, that the temperature produced must be aqual to that which can be derived from the sun. Sir Humphrey Davy had a Galvanic battery erected for him at the Royal Institution, by which he was enabled to fuse every substance exposed to its influence, and by which he decomposed the various earths, that had formerly been considered to be simple bodies, and determined many other important chemical facts.

270. *The temperature of animal bodies* is independent of the surrounding atmosphere, or other medium in which they live; for it is found that the heat of the human body is nearly the same all over the world. Living bodies exhibit a remarkable difference from unorganized matter in this respect: the latter soon acquire a temperature similar to that of the bodies by which they are surrounded; for instance, a candle, if brought into a room, of which the temperature is very high, begins to melt; if some water is exposed to the air, when it is below 30 degrees, the water is frozen: thus, in both instances, we see how readily unorganized matter acquires the same temperature as that of the medium in which it is placed. This, however, is not the case with living bodies; they maintain an equal temperature, with very slight variation in summer and winter, at the Poles, and at the Equator. To do this it is necessary that they should be enabled, in a cold climate, to generate a great quantity of heat, and in a hot climate, to dispose of it readily.—At present, we have merely to describe the manner in which animals generate heat; but in the experiments which follow, will be found several illustrations of the mode in which the superabundant heat is disposed of.. (See 289.)

271. The phenomenon of respiration is analogous, in many respects, to combustion. The blood circulating in the veins contain a considerable quantity of carbon; and before the blood can circulate through the body, to perform its various functions, it is necessary that this carbon should be removed. This is effected in the lungs. The blood is conveyed there, in an impure state, in very small blood vessels, which are permeable to the air, and are placed over small globules of thin cellular tissue, being the terminations of the windpipe. When we inspire the air, it is conveyed to these globules, or air-cells; and, passing through them, enters the blood: the oxygen of the air then combines with the carbon, and forms carbonic acid, just the same as it is formed when we burn a candle, in a glass, under water. (See experiment 306). This carbonic acid, mixed with the nitrogen of the air, is given out when we expire our breath; and its qualities may be proved by experiment 117. Now we know, in the case of the candle, that the union of its carbon with oxygen occasions heat; and the same effect is produced in the lungs. The formation of carbonic acid there is attended with the evolution of heat, and this is conveyed by the blood to every part of the body. (See experiment 309.(

The means by which the same temperature is maintained by the body, in cold weather as in hot, are vital; for when we are exposed to cold, an impulse is given to the function of respiration, by means of which, the blood is more frequently brought into contast with the air, and, consequently, a greater degree of heat is generated.

272. *Spontaneous combustion* can hardly be enumerated among the general sources of heat, since it occurs so seldom. Instances are recorded, however, in the scientific journals, of several well-authenticated instances, in which persons have been discovered burning slowly away, somewhat in the way that phosphorus burns, at a low temperature, in the atmosphere. It appears, indeed, as if the body underwent some change, by which a considerable portion of it was changed to phosphorus, or some substance very nearly resembling it. Phosphorus is principally formed from animal matter; and the supposition has, therefore, some support. But, as the instances when this peculiar mode of generating heat have

occurred but seldom, philosophers have not had sufficient opportunities of investigating the phenomenon satisfactorily.

Having thus explained the distinction between *latent* and *sensible* heat, and described the principal means by which it is obtained, it only remains for us now to describe generally its effects. This may be done briefly, because, in the following experiments, these are fully illustrated.

273. *Heat expands bodies.* This is a universal law, and there are but one or two apparent exceptions. Were there no such thing as heat, liquids and gases could not exist; all matter would be solid. Heat is the cause of bodies becoming fluid; it insinuates itself between the particles of which they are composed, and forces them further apart: if a great degree of heat is applied, the particles are separated so far, that they then assume the form of gas. Steam is a familiar example; and the thermometer acts solely on this principle. There are only two or three exceptions to this law, and they are only so in appearance. The principal one is water, which, instead of contracting when cooled down below 32 degrees, expands, when it assumes the form of ice. This is a beautiful provision, since the ice, floating on the water, prevents it parting readily with its heat, and thus does not allow our rivers, &c, to become a solid mass of ice, as they otherwise would. The cause of the water expanding, and becoming lighter when it freezes, is because the crystals of ice have interstices between them, which are filled with air.

274. *Heat has a tendency to equilibrium;* it endeavors to produce, in all bodies, the same degree of temperature: it is, therefore, constantly given off from objects which are hotter than those by which they are surrounded—1st, by radiation (see experiment 298): 2dly, by conduction (see experiments 290, 292, 294); 3dly, by reflection (see experiment 297). The wonderful effects produced by these means are fully described in the following experiments; and it is unnecessary, therefore, to do more than allude to them in this introduction.

EXPERIMENTS IN HEAT.

Sensations of heat—Various theories respecting—Latent heat—In Iron—In water—In a common button—Developed by friction—In the air—Production of heat by percussion—Expansion of bodies by heat—Cold by evaporation—Conducting powers of different substances—To break glass in any direction by heat—Cooling power of wire gauze—Dr. Franklin's experiment on heat of colored cloths—To break a roll of sulphur by the heat of the hand—Prince Rupert's drops—Reflection on heat—Formation of dew—Water boiled by being cooled—Production of freezing mixtures—Condensation of steam—Brightness of flame—To prove that flame is hollow—How a candle burns—Oxygen necessary for combustion—Requisites to produce a flame—Intense and rapid combustion—Detonation with sulphur and chlorate of potass—Vivid combustion under water—Detonation of chlorate of potass.

To sum up what has been stated above, the student will bear in mind the following principles, which the experiments will illustrate:—That heat exists in two distinct states—as sensible heat and as latent heat; that it may be procured, both naturally and artificially, by the methods which have been described; that it has a tendency to increase the bulk of all bodies it combines with, and diminish the bulk of those it separates from; and that it is constantly passing from one body to another, endeavoring to restore an equilibrium by the means just enumerated.

SENSATIONS OF HEAT DECEPTIVE.

275. If we place one of our hands in a basin of *hot* water, and the other in a basin of *cold* water, and then immerse both of them in another basin containing *luke-warm* water, we shall feel it to be cold to the hand that had been placed in the hot water, and hot to that which had been immersed in the cold. Our sensations of heat are very apt to deceive us.

276. Two travelers arriving at a spot half way up a mountain, will feel the temperature of the place to be hot or cold, according to the warmth of the place they have each of them left. The man *ascending* the mountain will feel cold, because the higher we ascend in the air the colder it is; while the traveler *descending* will feel warmer, for the same reason. Thus, any particular part of a mountain may appear agreeably warm to one man, and intensely cold to another.

LATENT HEAT.

277. A quantity of heat exists in all bodies in what is termed a latent state; that is, it cannot be felt by the touch (see Introduction, 263). The following experiments will, however, illustrate the fact better than any description can.

278. Hammer a piece of cold iron for a short time, and it will become exceedingly hot; if hammered briskly on an anvil, it may be made *red-hot.*

279. Rub a common brass coat-button, for a short time on a piece of wood; on applying it to the hand, it will be found to have acquired a high degree of temperature.

LATENT HEAT IN IRON.

280. The quantity of heat which exists, in a latent state, in iron, may easily be shown by the common flint and steel of a tinder-box. On striking the steel sharply with the flint, a portion of the latent heat of the former is given out, sufficient to melt a particle of the iron, and render it red-hot. If the flint and steel be struck sharply together, several times, over a clean sheet of writing-paper, a number of black spots will be found on it, which are the particles of steel that have been melted, and fallen on the paper.

LATENT HEAT IN WATER.

281. Water contains much heat, in a latent state; and if we could compress it with the same ease that we can many other, bodies, we might squeeze this heat out, and render it sensible to our touch. The same effect, however, may be produced in another way. Pour about a wine-glassful of sulphuric acid (common oil of vitriol) into a Florence flask, or other thin glass bottle, that will, therefore, bear a sudden degree of heat, without breaking; into the flask pour about twice or three times the quantity of water, and in a few minutes, although both the liquids were cold when mixed, a very great degree of heat will become sensible. Indeed, if the flask be immersed in water, a sufficient degree of heat may be obtained, by this means, to make it boil.—

Phosphorus may also be very easily ignited by its

The cause of this effect is believed to be as follows:—The sulphuric acid has a very strong affinity for water, and combines with it so intimately, that the liquids, when mixed together, do not measure so much as the sum of their measure when separate. Thus, a pint of sulphuric acid, mixed with a pint of water, would not fill a quart measure. It is evident, therefore, as the liquids have decreased in bulk, a portion of the latent heat that belonged to them must be given out in their changing to a more solid state; and this is the result that is produced. Care must be taken, in making the experiment, to hold the Florence flask so that, if it breaks with the heat, the mixture within it shall not fall on the clothes or furniture, as, otherwise, they will be much injured. Thin glass vessels bear a sudden degree of heat much better than thick ones, and a Florence flask is, therefore, well adapted for the experiment.

LATENT HEAT IN A COMMON BUTTON.

282. If we take a common brass button, and rub it smartly for a few minutes on the floor, or against a piece of wood, it will become hot enough to ignite phosphorus. At school, boys are practical philosophers when they perform this experiment, and illustrate its effects, by placing the hot button against the hands of their companions. who may not be aware of the effects of friction in developing latent heat.

LATENT HEAT DEVELOPED BY FRICTION.

283. Friction is one of the modes of procuring artificial heat; and savages are said to procure fire through its means alone (see Introduction). If two pieces of dry wood be rubbed together for for some time, they become heated; and if the friction is continued, they may be made to in flame. Large tracts of forests have frequently been set on fire by these means in winter time, when the boughs, being dry, the agitation of them against each other, by high winds, produce sufficient heat to ignite them. Sir Humphrey Davy even obtained heat from ice, by friction: he rubbed two pieces together in *vacuo*, and the latent heat developed by this means was sufficient to melt a portion of the ice. The effect of friction, in producing heat, is seen when a coach is going down a hill, with the "skid" on one of the wheels: sometimes the heat produced is so great, that it has been known to set the wheel on fire.—Great care is taken in constructing machinery to provide against friction; not merely because it impedes the action of the machine, but also to prevent the heat that would otherwise be produced, which might prove of serious injury. The experiment (282) with a common button is a good example of the effects of friction in producing heat.

LATENT HEAT IN THE AIR.

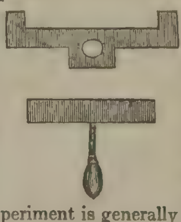
284. To exhibit this, an instrument is sold at the philosophical instrument-makers, called an air syringe, or "the philosopher's tinder-box;" but the same effect may be produced by a common popgun, which it very much resembles.—Stop up the end of a popgun with wax, or some other substance, so securely, that no air can escape, and make the rammer to fit the tube as tightly as possible, by greasing it. If a piece of tinder be then placed in a little hole, which must be made at the end of the rammer, and it is driven down quickly, and withdrawn again into the air, the tinder will be ignited. This is caused by the heat that is given out on the sudden compression of the air in the tube; and if the apparatus is made air-tight, a light may be produced by this means much easier than by a flint and steel (see Introduction). Although a popgun will do, a metal tube, stopped at one end with a piston, to fit air-tight, is better.

PPRODUCTION OF HEAT BY PERCUSSION.

285. The experiment (280) with the flint and steel is an example of the development of heat, by what is termed percussion, or the sudden striking together of two bodies. Blacksmiths frequently employ another plan to light their fires. If a piece of iron be laid upon an anvil, and struck sharply with a hammer for some time, it may be made red-hot; the hammering causing the iron to give out nearly all its latent heat.—The effect may be shown by merely beating a common nail with a hammer for some time, when it will become warm enough to ignite a piece of phosphorus; but if we wish to light a match by this means, we must use a large piece of iron, and beat it upon an anvil, or something similar. The use of the latent heat in the iron, which is forced out by this means, was to make it malleable and ductile, both of which properties it loses when its latent heat is forced out.

EXPANSION OF BODIES BY HEAT.

286. Measure a bar of iron, and afterward place it in a fire till it becomes red-hot, when it will be found, on again being measured while in that state, to have increased in length. When it cools, it will be of the same length that it was before being exposed to the fire (see Introduction). The annexed cut represents the iron rod and measure by which this experiment is generally performed.



287. Fill a phial with spirits of wine, and then immerse it, nearly to the mouth, in hot water.—The heat will expand the alcohol so much, that it will run over the sides of the phial. When it is taken out of the hot water, and cooled, the quantity that has been forced out will be seen by noticing how much would then be required to fill the bottle.

COLD BY EVAPORATION,

288. Evaporation produces cold, because a fluid, when it assumes the form of vapor, abstracts a portion of heat from the body from which it evaporates (see Introduction). To prove this, place a small quantity of ether on the back of the hand, and as it evaporates, considerable cold will be felt. When persons catch cold after getting their clothes wet, it is in consequence of the evaporation of water cooling the body so much, that the blood-vessels of the skin are unable to perform their accustomed functions. This is the reason why it is always important to put off wet clothing as soon as possible, and to keep

up the heat of the body by some stimulating drink, or, what is better, by exercise.

CONDUCTING POWERS OF DIFFERENT SUBSTANCES.

289. Some substances will allow heat to pass through them much easier than others. The former are called good conductors; the latter, bad. If we place a piece of thick iron wire in the fire, it will soon become so hot that we cannot hold it; but if we use a piece of glass, we shall find that we can handle it without inconvenience, even when one end is intensely heated. In this case, the iron is a good conductor, while the glass is a very bad one. Advantage is taken of this circumstance in manufacturing many domestic articles—for instance, the handle of metal teapots is made of wood, because, otherwise, the hand would not be able to bear the heat that would be conducted to it.

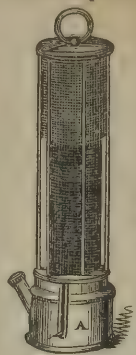
TO BREAK GLASS IN ANY DIRECTION BY HEAT.

290. Glass being a bad conductor of heat, advantage may be taken of the circumstance to break a piece in any direction, as follows:—Dip a piece of worsted thread into spirit of turpentine, and put it round the glass, in the direction required to be broken; then set fire to the thread, and the glass will crack exactly in a line with it. A piece of red-hot iron may be used for the same purpose, but the effect can be produced more easily with the worsted.

COOLING POWER OF WIRE GAUZE.

291. If a piece of wire gauze be held in the flame of a candle, it will be seen that the flame *will not pass through it.* This is in consequence of the metal conducting away the heat so rapidly from the gaseous tallow, in passing through, that when it reaches the other side, it is not sufficiently hot to combine oxygen, and therefore passes away in the form of smoke. That such is the case, may be proved by applying a light to the smoke, which will then ignite, and burn like the flame beneath.

292. The safety-lamp of Sir Humphrey Davy was the result of his discovery of the cooling powers of wire gauze. Before this lamp was invented, the men employed in coal mines were exposed to great danger, in consequence of the frequent explosions that took place when a stream of explosive gas, called fire-damp, came in contact with their candles. This gas, which very much resembles the common gas used in our shops, is very explosive when mixed with air, and is formed in fissures in coal in the mines. It frequently happened, therefore, that when a miner was at work, he liberated a quantity of this gas, which, mixing with the atmosphere around, became as explosive and destructive as gunpowder; and when it came in contact with a light, its effects were as destructive. Accidents were so frequently occurring, and so many men were killed, that at last a society was formed, to endeavor to find out some means of preventing them; but their efforts were unsuccessful. At length they applied to Sir Humphrey Davey, who, on experimenting on the gas, discovered that it would not explode unless it came it contact with flame; and he thought that if, therefore, a light could be enclosed, so that while a sufficient quantity of air should be supplied to it to keep it burning, the flame should be prevented communicating with the air without, that a perfect safety lamp would be provided for the miner. After a variety of experiments, he constructed one similar to that represented in the accompanying wood-cut. It represents a common lamp, surrounded with a shield of iron wire gauze, which has the same effect in extinguishing flame, when it endeavors to pass through, as a piece of gauze has with a candle. When, therefore, the miner, with his lamp, is suddenly surrounded with a quantity of explosive gas, he is no longer in danger; because the flame of the lamp cannot pass through the gauze to explode the gas. So effectual, indeed, is this simple piece of apparatus, that it is found, even when the gauze becomes red-hot from the quantity of explosive gas burning *within* the lamp, that it will not explode that on the outside. And from a knowledge of the simple property of wire gauze, which any one may illustrate with a candle, the philosopher has been enabled to construct an instrument which has been the means of saving the lives of thousands.



DR. FRANKLIN'S EXPERIMENT ON HEAT OF COLORED CLOTHS.

293. On a winter's day, when the ground is covered with snow, take four pieces of woolen cloth, of equal dimensions, but of different colors—viz. black, blue, brown, and white, and lay them on the surface of the snow, in the immediate neighborhood of each other. In a few hours the black will have sunk considerably below the surface; the blue almost as much; the brown evidently less; while the white will remain nearly even on the surface. Thus, it appears that the sun's rays are absorbed, and conducted through them to the snow, much more rapidly than by the other colors. And it is, perhaps, for this reason, that dark-colored clothes are preferred in winter, while lighter ones are considered more suitable for summer.

TO BREAK A ROLL OF SULPHUR BY THE HEAT OF THE HAND.

294. Sulphur is a very bad conductor of heat. If a roll of it be held in the warm hand for a few minutes, it will snap, and break into two or more pieces. If it be held over the flame of a lamp, it will crumble, and separate still more. Breaking a roll of sulphur, by the mere heat of the hand, is a very pleasing illustration of the effects of heat.

PRINCE RUPERT'S DROPS.

295. The little glass toys, known by this name, may be purchased at any glassblower's, for about sixpence a dozen; and they illustrate, in a very striking manner, the effects of heat on bad conductors. Glass is a bad conductor, and this is a cause of its being frequently broken. If hot water is poured suddenly into a tumbler, the interior expands before the heat can affect the outside, and it therefore tears the particles on the

outside from each other; in other words, it cracks the glass. This is the reason why it is necessary to have retorts, and other kinds of chemical apparatus, intended to be exposed to much heat, made very thin, in order that the heat may pass readily through them. Prince Rupert's drops are lumps of glass, let fall, while melted, into water, and are thereby suddenly cooled and solidified on the outside, before the internal part is changed; then as this at last hardens, and would contract, it is kept extended by the arch of external crust to which it adheres. Now, if a portion of the neck of the lump be broken off, or if other violence be done, which jars its substance, the cohesion is destroyed, and the whole crumbles to dust, with a kind of explosion. Any glass cooled suddenly when made, remains very brittle, for the reason now stated. What is called the *Bologna jar*, is a very thick, small bottle, thus prepared, which bursts by a grain of sand falling into it. The process of annealing, to render glass-ware more tough and durable, is merely the allowing it to cool very slowly, by placing it in an oven, where the temperature is caused to fall gradually.

REFLECTION OF HEAT.

296. Bright substances reflect heat much better than dark and rough ones, which absorb it best. If a piece of tin be held before the fire, it will take some time before it becomes hot, because it reflects the light and heat; but if it be covered with lamp-black, it will soon become heated. Meat-screens for our kitchen fires are formed on this principle: they reflect the heat on to the roasting meat.

FORMATION OF DEW.

297. Dew is deposited on the leaves of plants, in consequence of their giving out so great a quantity of heat, by radiation, on clear, bright nights, when there are no clouds, that the temperature of the plant is reduced below that of the atmosphere. When this takes place, the heat of the atmosphere is absorbed by the plant, and is, consequently, unable to retain so great a quantity of moisture; warm air possessing the power of holding more vapor in it than cold air. The manner in which dew is deposited on plants may be seen, by bringing a glass of cold water from a well into a warm room. The cold water absorbs some of the heat of the surrounding air, which, in passing through the sides of the glass, leaves behind the water it contained in a state of vapor: this will be seen on the glass. Water decanters show this in summer.

WATER BOILED BY BEING COOLED.

298. Water boils, on the surface of the earth, at a temperature of 212 degrees; but on the tops of high mountains, where the weight of the atmosphere is somewhat less, the boiling point is lower than 212 degrees. To prove that the pressure of the atmosphere has great influence over the boiling point, the following striking experiment can be performed:—Fill a Florence flask about half full of water, and then expose it to the heat of a spirit-lamp until it boils; when this takes place, put a cork in the flask, and remove it from the lamp, when the steam will be condensed. In a very short time, however, if the bottle has been corked tightly, so that the air cannot enter when the steam is condensed, the water will begin to boil again; and if the flask is placed in *cold* water, the boiling will be still more violent. If the flask be then removed from the cold water, and placed in *hot* water, the boiling will cease.

The cause of this apparent anomaly is, that when the flask is placed in cold water, the steam or vapor in the bottle is condensed; and there being, therefore, little or no pressure on the surface of the water, the air having been expelled by the steam, the heat contained in the water is sufficient to cause it to boil, and the additional heat imparted to it by the hot water makes it boil rapidly. When the flask is placed in the hot water, a vapor is formed, which presses on the surface, similar to the atmosphere; and, consequently, prevents the liquid boiling, except at a higher temperature. Water will boil at 90 degrees in *vacuo*, and when the steam is condensed in the flask, there is a very good vacuum formed above the water; so that, indeed, the warmth of the hand is then almost sufficient to make the water boil.

PRODUCTION OF FREEZING MIXTURES.

299. Liquids, when they become more dense, or solid, give out heat (as in experiment 281;) solids, when they are rendered fluid, without the application of heat, become very cold. Advantage is taken of this circumstance to produce what are termed frigorific mixtures. The following may be formed, without much trouble, and will illustrate the fact very well.

300. Mix two parts of snow, or pounded ice, with one of common salt. The mixture soon becomes liquid, and the temperature falls 41 degrees below the freezing point of water. To produce this effect, a quantity of the materials must be used. From a knowledge of the effects of salt upon ice, it is frequently used, during a frost, to melt the ice upon the pavement, &c.

301. Mix sixteen parts of water with five of nitre, and five of sal ammoniac, in fine powder, when the temperature will fall about 40 degrees below the freezing point. The former experiment can only be conveniently performed in the winter; but this can be produced at any time.

CONDENSATION OF STEAM.

302. Water, when exposed to a heat of 212 degrees, is formed into steam. In this state, the particles that compose water are so far separated by heat, that it is found steam occupies the 1,700th space of an equal weight of water. When, however, the heat is abstracted, the steam is condensed into the original quantity of water from which it was formed. To prove this, procure a Florence oil-flask, and boil a small quantity of water in it; when the steam is issuing from the mouth, put in a cork, having previously covered the hand with a towel, to prevent the steam scalding the hand. If the flask be now placed in cold water, and the cork taken out, the steam will be condensed, and the water will rush into the bottle, and completely fill it. This is sometimes effected with so much force, that the flask is driven out of the hand, and even broken; care must, therefore, be used in performing the experiment.

BRIGHTNESS OF FLAME.

303. The brightness of a flame depends upon

the quantity of oxygen it receives, as may be shown by a common candle. If we examine the flame, we shall perceive, that on the outside it is bright, while there is a cone, of a dark color, in the centre: this part, indeed, is *not a light*, as may be proved by holding a clean card, for a minute, in the centre of a flame; on withdrawing it, there will be found a dark circle—showing that it was only the outer portion of the flame, in contact with the air, that was capable of burning the card. If all the tallow were consumed, there would be no smoke; for smoke is the particles of tallow, passing off in an unconsumed state. In the common lamps, used by butchers, the waste in this way is very great; and before the introduction of the Argand burner for lamps, this was an evil that could not be remedied. The inventor of this burner considered, as the brightness of a flame, and the complete combustion of the material, depended upon the supply of oxygen, that if, instead of having the wick of a lamp in a solid piece, like the wick of a candle, it were made hollow, or so that it might be placed round a hollow cylinder, the combustion would be more perfect. He accordingly constructed a lamp, with a burner of this kind, and the effect he anticipated was produced: at the same time, he found that, by using a glass cylinder, similar to the common gas-glasses, that the draft was promoted, and a greater supply of oxygen afforded to the flame. This invention has since been universally adopted; and gas-burners are constructed. on a similar principle. In lamps, the wick, which is hollow, is placed round a brass tube, and can be raised, or dressed, at pleasure; the lower end is placed in oil, which it absorbs, and brings gradually in contact with the flame; a glass is placed round this, and air is supplied to the interior of the flame through the tube, and to the exterior in the ordinary way.

HOW A CANDLE BURNS.

304. The combustion of a candle (see Introduction) illustrates many natural laws in a simple manner. When the wick is lighted, it melts a portion of the tallow immediately beneath, and forms a little cup, in which a quantity of the liquid tallow continues. The wick, by capillary attraction, draws up a portion of this tallow, which enters the flame. Here it becomes a gas, and combines with the oxygen of the atmosphere, forming carbonic acid. A portion of the gas formed from the melted tallow may be ignited away from the candle, by placing a small tube, rather wider than the bore of a piece of tobacco-pipe, in the dark part of the flame: the gas will pass through this, and if a light be applied at the other end, it may be ignited. The existence of the carbonic acid may also be shown by holding a lighted match a little above the candle, when the former will be extinguished.

305. The benefit of the Argand burner will be seen immediately, if we place a card at the bottom of the tube, so as to stop the supply of air to the interior of the flame. The consequence will be, that much of the oil will be unconsumed, and the lamp will give off a great deal of smoke.

TO PROVE THAT FLAME IS HOLLOW.

306. Drop, carefully, some spirits of wine on the surface of water, within a small hoop, floating in a large basin; set the spirits on fire, and then introduce the finger under the edge of the hoop, and up through the water, into the interior of the flame. If this be done carefully, no heat will be felt, except the finger is raised sufficiently high to touch the film of flame itself.

OXYGEN NECESSARY FOR COMBUSTION.

307. Put a little water in a soup-plate, and on it place a piece of wax taper, or candle lighted, so that it may swim on the surface; then take a common beer tumbler, and cover the taper over with it: the consequence will be, that, after a short time, the light will be extinguished, and the water from the plate will rise a little way in the tumbler. This experiment shows the necessity of oxygen in combustion; for directly the light had absorbed all of it that was contained in the air under the glass, it went out. The rising of the water is in consequence, principally, of the cooling of the air again within the tumbler; while it was heated, a portion was driven out, and on cooling, the water supplies its place, being forced in by the pressure of the air on the outside.

308. Another experiment, illustrating the same fact, may be performed in the following way:—Take a large wide-mouthed bottle, with the bottom broken off, and place it a little way in a pail of water; then hold the nostrils close with one hand, and breathe the air in the bottle several times. By this means, the greater portion of the oxygen contained in the air in the bottle will be absorbed, as we all abstract oxygen from the air every time we breathe. When the mouth is withdrawn from the mouth of the bottle, place the hand over it, and get a person to introduce into it a lighted match, which, it will be seen, is instantly extinguished. Instead of using a bottle, a better piece of apparatus is a common gas-receiver.

The *rationale* of both these experiments is nearly the same. In the first, the burning taper absorbs the oxygen, and forms carbonic acid gas: in the second, a similar effect is produced by the carbonaceous matter of the blood uniting with the air in the bottle, and forming the same gas. This gas will neither support life nor flame: and if, therefore, a living animal, or a light, be introduced, the first should be killed, and the latter extinguished.

310. The use of the bellows, in making a fire burn brighter, is simply because they force a greater quantity of air, and consequently, more oxygen, against the burning material than it would otherwise receive. The damper of a chimney produces an effect precisely opposite, by lessening the supply of air sent to the fire.

REQUISITES TO PRODUCE FLAME.

310. There are several requisites for the production of a flame, and without which, it cannot exist. The first is, that oxygen must be pre-

sent, in some form, to support combustion; and the second, that the body must be heated to a high degree of temperature. There is one exception to the first of these requisites, since bodies will burn in chlorine gas, which it has been proved does not contain oxygen.

311. Flame is the intensely heated particles of a burning body, in the act of uniting with oxygen. Thus, in the case of a common lamp, the oil is absorbed by the wick, and the particles, when they enter the flame, become white-hot, and then pass off as a gas. Experiment 308 will show the necessity for oxygen to support combustion; and it is, therefore, only necessary to prove, that whatever lowers the temperature of a burning body destroys flame.

312. Get a piece of wax candle, and pull all the wick out except one thread, so that, when this is lighted, the flame shall be very small. Then make a little ring of iron wire, about the eighth of an inch in diameter, which affix to a handle. It will be found that if, when the wick is lighted, this wire ring is passed over, so as to go below the flame, that it will be immediately extinguished. This is in consequence of the iron wire being a good conductor, and, therefore, the heat of the flame is carried away so quickly by it, that the wax cannot become white-hot, and unite with the oxygen of the atmosphere; the flame is, therefore, extinguished. The wax, in a gaseous state, will not combine with the oxygen, unless at a high degree of temperature; and it is evident, therefore, that anything which cools the wax must prevent the combination taking place.

313. A similar effect to that produced by the cold ring of wire may be shown, by merely bringing a penny piece, or other good metallic conductor, in contact with the flame. When the candle has been extinguished by this means, light it again, and make the ring of wire hot; then pass it again over the flame, and it will not put it out.—This shows, satisfactorily, that, in the former instance, the effect was produced simply in consequence of the rapid absorption of the heat by the metal.

INTENSE AND RAPID COMBUSTION.

314. To illustrate the sudden combustion of bodies, through intense chemical action, the following experiment may be performed:—Mix a little *chlorate of potass*, about the size of a pea, with the same quantity of *loaf sugar*, having previously reduced them each to powder. Place the mixture on a piece of tile, or iron, and dip a glass rod into a bottle of sulphuric acid; let the acid from the rod drop upon the mixture of chlorate of potass and sugar, and they will immediately flame.

Care must be taken in making this experiment, not to use a large quantity of the materials employed: the effect will be produced as well with the quantity we have mentioned, as if it were twenty times as great, and there is no danger attending the experiment; but if a large quantity be used, the matter will perhaps fly about, and might occasion injury. The face must be kept from the mixture when the sulphuric acid is dropped into it, as it bursts into flame almost instantly.

The *rationale* of the experiment is, that the chlorate of potass and the sulphuric acid have a powerful affinity for each other, and when they come in contact, they combine with great intensity; much heat is, therefore, given out—sufficient to ignite the materials. The loaf sugar is used, because it burns readily, and thus affords material for the potass and acid to act upon: that this is its only use, may be seen by mixing some of the chlorate of potass with sulphuric acid by themselves, when the effect will more resemble an explosion than the combustion that ensues in the former instance.

315. If equal parts of chlorate of potass and camphor, mixed together, be touched with a drop or two of sulphuric acid, the camphor will inflame. The same effect takes place with spirits of wine, or charcoal, instead of camphor.

These experiments must be conducted with care.

DETONATION WITH SULPHUR AND CHLORATE OF POTASS.

316. Into a mortar put two or three grains of chlorate of potass; and after having reduced it to powder with the pestle, introduce some flour of sulphur, or brimstone, very finely powdered. If the two be now rubbed together, they will be detonated, with a smart noise, like the cracking of a whip; and this may be repeated a dozen times, with the same quantity of materials. This is a very pleasing experiment, quite unattended with danger of any kind.

VIVID COMBUSTION UNDER WATER.

317. Place a small piece of phosphorus, and a few grains of chlorate of potass, in a tumbler, or other vessel, and pour on them, gently, some *hot* water. This will inflame the phosphorus, and its combustion, being supported by the chlorate of potass, a very pleasing and vivid light will be witnessed under the water.

318. If a little oil be placed on the top of the water in the vessel, it will be inflamed.

DETONATION OF CHLORATE OF POTASS.

319. Many substances, when heated to a certain degree of heat, change their form, with an explosion. If *a little* chlorate of potass be put on a fire-shovel, and placed over the fire, when the shovel has received a certain heat, the chemical detonates, with a sharp report.

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